

PLANT AND ANIMAL RESPONSES ON GRAZED PASTURES  
OF 'FLORAKIRK' AND 'TIFTON 85' BERMUDAGRASSES

By

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Dedicated to the memory of my grandfather,  
Dr. Luis Silveira Pedreira, Professor of Chemistry.

Example of character.

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By

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'Florakirk' and 'Tifton 85' are the most recently released bermudagrasses for the livestock industry of the southeastern United States. Data are lacking on the potential of these forages, and management guidelines are needed for their use by North Central Florida cow-calf enterprises. The objectives of this research were (i) to measure plant responses of Florakirk to a range of grazing managements and (ii) to compare forage and animal production on Florakirk and Tifton 85 pastures under grazing. In one study, Florakirk was grazed to stubble heights (SH) of 8, 16, and 24 cm at grazing cycles (GC) of 7, 21, and 35 d during two grazing seasons. In 1993, herbage accumulation (HAC) was maximized ( $13.1 \text{ Mg ha}^{-1}$ ) under the 7-24 combination of GC-SH. In 1994, the 35-24 treatment resulted in highest HAC ( $17 \text{ Mg ha}^{-1}$ ). In both years, minimum HAC was associated with intermediate GCs for any level of SH. Concentration of crude protein (CP) in hand-plucked herbage

ranged from 96 to 113 g kg<sup>-1</sup> in 1993 and from 121 to 134 g kg<sup>-1</sup> in 1994. Lowest CP was associated with long GC. In vitro digestible organic matter concentration (IVDOM) was highest for short SH and long GC in 1993 but intermediate GCs in 1994. Neutral detergent fiber (NDF) concentration was not affected by treatments.

Botanical composition was not affected by grazing treatments, and proportion of Florakirk on all pastures was 96% or greater at the end of the second year of grazing. Short SHs were associated with low postgraze canopy light interception but did not have apparent detrimental effects on stand condition. Florakirk responded to close, frequent grazing by assuming a prostrate, turf-like growth habit. Florakirk reserves were stored mainly in rhizomes. Treatment effects on plant reserve status were relatively small and not consistent across years.

In the second study, pastures of Florakirk and Tifton 85 were continuously stocked with yearling beef heifers during the warm season using a variable stocking rate. Seasonal HA and growth rates were higher for Tifton 85 resulting in higher average stocking rate than on Florakirk (7.7 vs. 5.5 heifers ha<sup>-1</sup>). Average daily gain (ADG) was the same for the two grasses (0.52 kg). Because carrying capacity of Tifton 85 was higher than that of Florakirk, gain per hectare was also higher (648 vs. 447 kg ha<sup>-1</sup>). Herbage allowance rather than nutritive value had the greatest effect on seasonal patterns in ADG. Concentrations of IVDOM and NDF were higher for Tifton 85, but CP was higher in Florakirk. These data suggest that under continuous stocking in North Florida, there are advantages of Tifton 85 over Florakirk in productivity, digestibility, and possibly persistence.

## CHAPTER 1 INTRODUCTION

Grasslands have been important to humankind since prehistoric times. They were vital to early peoples long before cattle (*Bos spp.*) were domesticated (Barnes and Baylor, 1995), providing the forage on which wild grazing animals fed and fell prey to human hunters. Through history, grasses and grasslands have been key elements in the process of colonization of new frontiers such as the arrival of European settlers in the American continent during the 15<sup>th</sup> and 16<sup>th</sup> centuries. They brought their cattle upon which they depended for survival and prosperity, and made use of existing grasslands to maintain their herds.

More recently, grasses and grasslands continue to represent a valuable resource to man. With an ever-increasing world population and the prospect of food shortage, malnutrition, and hunger (already a reality in some parts of the world), the production of high quality food (e.g., animal products) deserves increasing attention. Many developing regions — usually in the tropics and subtropics — could benefit from increased availability of animal products. Even in more developed areas where those products are usually not in short supply, increased efficiency in production might allow for a reduction in cost, making high-quality food more accessible to lower-income segments of society. Devising improved feeding strategies in livestock

production, including better forage and pasture technology has the potential to deliver such increments in efficiency of production.

Mannetje (1978) discussed alternatives for pasture improvement in the tropics. He explained that pasture improvement ranges from the inclusion of a legume into existing pastures to the complete replacement of existing vegetation by more productive grasses and legumes which, in order to persist, may require significant inputs in terms of fertilization and management. He also stated that at each increasing level of input, a corresponding increase in output (e.g., beef production) is likely to occur. While current beef production in the tropics is a small fraction of what is physically possible, the biggest constraints to development are lack of capital, knowledge, and motivation.

When compared with temperate regions, productivity levels of forage-livestock systems in the tropics are lower and this is usually associated with the poorer feeding value of tropical pastures (Minson, 1981). Although net primary production in tropical grasslands may be several times those of the most productive temperate grasslands, a much smaller proportion of what is produced may be recovered by the grazing animal (Mott, 1983). This failure of tropical pastures to give higher yields of animal product, commensurate with their greater net primary production, can be accounted for by several factors, including greater losses in the grazing process and lower intake of energy above maintenance. Mott (1983) also indicated that breeding and selecting grasses of high intake and digestibility rates, together with the

development of management practices that optimize pasture productivity and utilization, are important strategies for increasing yield of animal product per hectare.

The forage resource utilized in cultivated pastures of tropical and subtropical areas is diverse. Most of the pasture grass species utilized by commercial, intensive and semi-intensive livestock enterprises in tropical areas are from tribes of the Panicoideae subfamily (Bogdan, 1977; Leafe, 1988). Bermudagrass [*Cynodon dactylon* (L.) Pers.], a member of the Eragrostideae subfamily, is a stoloniferous perennial that finds worldwide distribution but is best adapted to lower latitudes and altitudes. In the US, bermudagrass is well adapted to the southeastern states where hybrid commercial cultivars comprise a significant portion of the forage resource used by the livestock industry, particularly in beef cattle production.

In Florida agriculture, the beef cow-calf enterprise is a major generator of revenue for the state's economy. As of 1 Jan. 1994, the beef cow herd numbered 1.1 million head and there were 1.02 million calves born in 1993 (Florida Agricultural Statistics, 1994). All cattle and calves on Florida farms and ranches, including dairy, totaled 1.98 million head. Although bahiagrass (*Paspalum notatum* Flüggé) is the forage grass most widely found on Florida's cultivated pastures, covering an estimated 1 million ha (Chambliss and Jones, 1981; Chambliss and Sollenberger, 1991), gains of cattle grazing bahiagrass are rarely greater than 0.45 kg d<sup>-1</sup> (Sollenberger et al., 1988). Other species such as limpograss [*Hemarthria altissima* (Poir.) Stapf. et C.E. Hubb.] and digitgrass (*Digitaria eriantha* Steud.) are also used to varying extents but problems related to low forage N concentration and poor cold

tolerance, respectively, have limited their use. In North Central Florida, the relatively cool winter temperatures hinder the persistence of the less winter hardy warm-season grasses such as the digitgrasses and stargrasses (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis* and *C. aethiopicus* Clayton et Harlan) (Mislevy and Brown, 1991; Mislevy et al., 1993a, b). Lack of winterhardiness has been associated with the absence of rhizomes.

'Florakirk' bermudagrass was released by the Florida Agricultural Experiment Station in 1994. It is a persistent, rhizomatous perennial grass, well adapted to the Panhandle and northern part of peninsular Florida which are too cold for stargrasses, but also grows well on South Florida flatwoods (Mislevy et al., 1995). Similar to 'Tifton 85', another recently released hybrid bermudagrass (Burton et al., 1993), Florakirk was developed at the University of Georgia Coastal Plain Experiment Station, in cooperation with USDA-ARS. Florakirk is an  $F_1$  hybrid between 'Callie' and 'Tifton 44', a cross that also produced 'Tifton 78' (Burton and Monson, 1988). Tifton 78 was released due to its better performance at Tifton, but at Ona, FL, Florakirk has shown faster establishment and greater DM yields than Tifton 78 (Adjei et al., 1989). In addition, Florakirk has persisted well for 15 yr under grazing and shown better tolerance of poor soil drainage than most bermudagrasses (P. Mislevy, personal communication; Sollenberger et al., 1995). Tifton 85, a rhizomatous  $F_1$  hybrid between 'Tifton 68' and PI 290844 from South Africa, was released due to its high yields, fast growth and spreading, and high digestibility.

Because the successful adoption of Florakirk and Tifton 85 bermudagrasses could have a positive impact on the beef cow-calf industry of North Central Florida, research was initiated in order to (i) assess the responses of Florakirk bermudagrass to a wide range of grazing management practices and (ii) comparatively quantify plant and animal responses on pastures of Florakirk and Tifton 85 bermudagrasses, continuously stocked with yearling beef heifers during the summer. Specific objectives were (i) to measure yield, persistence, and herbage nutritive value responses on Florakirk pastures grazed every 7, 21, or 35 d to a stubble height of 8, 16, or 24 cm, and (ii) to measure pasture productivity, herbage nutritive value, beef heifer average daily gain (ADG), gain per hectare, and pasture carrying capacity on continuously stocked Florakirk and Tifton 85 pastures, grazed during the warm season using a variable stocking rate.

## CHAPTER 2 LITERATURE REVIEW

### The Role of Improved Pastures in Ruminant Livestock Production in the Southeastern United States

Livestock production is an important segment of agriculture in most areas of the earth. In virtually all developing countries in tropical and subtropical areas, as well as in most warmer regions in developed countries, beef and dairy production are heavily based upon the forage resource available for livestock feeding. Crowder and Chheda (1982), based on G.T. Trewartha's climate classification, included a large portion of the southern US within the Cf climate type. This is described as "subtropical humid, with the rainy season coinciding with hot summers; relatively mild winters but with frost and occasional snow; located on the eastern side of a continent". By this classification, the entire southeastern US, southeastern Asia, most of eastern Australia, eastern South Africa, and a large portion of southeastern South America are all under the same climatic conditions.

In the US, the southeastern Piedmont and the Coastal Plain are sometimes referred to as the "Lower South". Compared to the rest of the continental US, the lower South is a distinct environment and this impacts on the predominant types of

natural vegetation present. More important, the environment affects adaptation of introduced plant materials, including the crop and pasture plant species.

Discussing pasture methods to maximize output of the cattle industry in the South, Burton (1970) described the region's native vegetation as timber, with an understory of shrubs and grass, growing on sandy soils very low in natural fertility. He compared the potential yield of animal output in this situation with the potential output on well fertilized 'Coastal' bermudagrass [*Cynodon dactylon* (L.) Pers.] and stated that on native vegetation, expected animal outputs are about 8 kg of liveweight gain (LWG) per hectare per year, whereas heavily fertilized Coastal bermudagrass can produce more than 2 Mg LWG ha<sup>-1</sup> yr<sup>-1</sup>. Writing on the cow-calf segment of the beef cattle industry in the US, Wilson and Watson (1985) explained that, traditionally, beef cows have been more important to the agricultural base in the western states. Recently, however, cow numbers have increased more rapidly in several Corn Belt states and most mid-South and Southeast states. In the Southeast, beef cows replaced or complemented other farm enterprises such as cotton (*Gossypium hirsutum* L.), poultry (*Gallus gallus* L.), citrus (*Citrus spp.*), and tobacco (*Nicotiana tabacum* L.) (Wilson and Watson, 1985).

Hoveland (1992) estimated that out of approximately 39 million ha of perennial pastures grown in the eastern US almost 30 million ha are located in the South. Pastures in the southern US are mainly used for beef cows and calves and stockering of weaned calves (Hoveland 1986; Wilson and Watson, 1985). The base forage systems in the South are predominantly built around two warm-season perennial

grasses, bermudagrass and bahiagrass (*Paspalum notatum* Flügge). These grasses grow well in the summer but are dormant for 4 to 6 mo, requiring a relatively long winter hay feeding period unless overseeded with cool-season annual grasses (Hoveland, 1992), a practice that can increase beef production by an extra 150 to 175 kg ha<sup>-1</sup> yr<sup>-1</sup> (Wilson and Watson, 1985).

Another alternative for improving the forage resource is the use of forage legumes, which in general, are capable of increasing the crude protein (CP) concentration and the digestibility of the forage diet. In the South, however, they cannot be considered an important pasture component (Hoveland, 1989, 1992). Because of lack of adapted germplasm, the instability and unreliability of legumes is the main reason for dependence upon grass-N pastures in the South. Some winter-annual clovers (*Trifolium spp.*) are sometimes used with reasonable success (Hoveland, 1992).

Mott and Moore (1977) discussed options for finishing cattle on high forage diets in the subtropical region of the South. They explained that common bahiagrass and carpetgrass (*Axonopus affinis* Chase) accounted for much of the planted pasture in Florida until the introduction of 'Pangola' digitgrass (*Digitaria eriantha* Steud.) and 'Pensacola' bahiagrass (*Paspalum notatum* Flügge var. *saurae* Parodi). The authors argue that the main reason for low animal outputs (LWG ha<sup>-1</sup>) was the low carrying capacity (CC) of the former two grasses. The introduction of the two improved grasses, associated with increased use of N fertilization or white clover (*Trifolium repens* L.) had a dramatic effect upon carrying capacity and animal average daily gain

(ADG). While unfertilized carpetgrass and bahiagrass produced ADGs of 0.23 and 0.24 kg, respectively, fertilized Pensacola and unfertilized Pangola gave ADGs of 0.5 and 0.6 kg, respectively (Mott and Moore, 1977). Carrying capacity on carpetgrass pasture increased from 57 to 136 steer days  $\text{ha}^{-1}$  when 34 kg  $\text{ha}^{-1} \text{yr}^{-1}$  of each N,  $\text{P}_2\text{O}_5$ , and  $\text{K}_2\text{O}$  were added. The same fertilization plus the incorporation of white clover on the pasture boosted carrying capacity to 652 steer days  $\text{ha}^{-1}$ . The authors concluded by suggesting that, among other research priorities in animal production systems in subtropical Florida, emphasis should be placed on the development and evaluation of forages with improved quality and persistence under the stress of the environment, including the grazing animal.

Even small pasture inputs can cause a substantial improvement in animal performance in the humid region of the US (Hoveland, 1992). Current levels of input in cow-calf systems are low and so is productivity per unit land area. If beef cattle production is to be maximized in the Southeast, the best grasses and management practices must be used together in effective feeding systems (Burton, 1970). Devising optimum management systems for new grasses that become available is key to maximizing beef cattle production in the South (Burton, 1970; Hoveland, 1992).

#### Plant-Animal Interactions on Grazed Pastures

Grasses have been grazed by herbivores for thousands of years (Pohl, 1987) and today we see only the plant and animal species that have survived this co-evolutionary struggle in which human participation is recent (Hodgkinson and

Williams, 1983). Crawley (1983) stated that there is a fundamental asymmetry in plant-herbivore interactions, with plants having more impact on the grazing animal than the other way around. This suggests that, in a grazed pasture situation, animals are more sensitive to variations in the pasture component than the pasture is to variations in the animal component. It is virtually impossible, however, to completely isolate and study individual components of the plant-animal interface, except under highly controlled, artificial conditions.

### Plant Responses to Grazing

When a pasture is grazed, individual plants either survive or die. According to Hodgkinson and Williams (1983), the surviving plants usually respond with changes in form and function but this degree of plasticity is variable among species and even among genotypes within a species. In general, it is accepted that most grasses have developed 'tolerance' mechanisms (those that facilitate regrowth following defoliation) although a few grasses (e.g., *Triodia spp.*) are able to resist grazing by repelling animals through 'avoidance' mechanisms (Vallentine, 1990).

### Morphological responses

Short-term effects of grazing can be seen in phenotypic changes as plants modify their growth habit. The shift from a more erect and sometimes clumped growth to a more decumbent, prostrate growth has been documented for several grass species. Kydd (1966) observed that plants of perennial ryegrass (*Lolium perenne* L.) responded to grazing by quickly assuming a prostrate growth habit. At high grazing pressures, Coastal bermudagrass [*Cynodon dactylon* (L.) Pers.] growth was

characterized by short, thick stolons producing leaves close to the stem (Roth et al., 1985; cited by Matches, 1992). In tall fescue (*Festuca arundinacea* Schreb.), Matches (1992) observed clumping when plants were lightly or infrequently grazed. In contrast, tall fescue develops a turf-like sward under frequent defoliation at moderate to heavy grazing pressures.

Although the extent of the morphological responses is variable across forages and even within grass species, they are all related to photosynthate availability and apical dominance (Youngner, 1972). Leopold (1949) claimed that the removal of apical meristems by grazing or cutting stimulates basal tillering by eliminating the source of auxin, which inhibits the development of lateral buds. Although not an exclusive feature of grasses, tillering is an indication of a highly specialized structural organization of the Gramineae. Tillers, which are grass phytomers (modular units of growth), consist of young vegetative lateral shoots growing upward within the leaf sheath. They are further organized into anatomically attached groups forming the complex graminoid plant (Langer, 1963; Vallentine, 1990). Though they are primarily under genetic control, tillering responses are largely influenced by environmental factors (Hyder, 1972). In grassland ecosystems tillering is stimulated by high irradiance levels, whereas at low irradiance levels growth of axillary buds is depressed as carbon is preferentially allocated to existing tillers (Phillips, 1969; Robson et al., 1989). Jewiss (1972) proposed that tillering is most likely under the control of both auxin and carbon supply. Such a control mechanism may be through the regulation of the supply of assimilates to the basal bud or through the supply of

another regulator to the bud. At the bud, the growth regulator controls cell division and cell expansion and acts as a precursor for the movement of assimilate into the bud. This has been named the 'nutrient-diversion' theory of apical dominance (Phillips, 1969; Jewiss, 1972).

In long-established grass swards, a turnover mechanism exists through which old tillers die and new ones are produced (Kays and Harper, 1974). In this situation a common tiller density (tillers area<sup>-1</sup>) is thought to be eventually reached so that tiller populations fluctuate around a base value. There is, therefore, a self-restriction mechanism whose severity seems to be proportional to plant (or tiller) population, despite the fact that individual tiller life span is relatively short (sometimes in the order of a few days) but regulated by the same mechanism of replacement (Robson et al., 1988; Robson et al., 1989).

Yield of forages is highly influenced by tillering. Knight (1961) showed that in orchardgrass (*Dactylis glomerata* L.), plant weight and number of tillers per plant were highly correlated, fluctuating in similar patterns over the growing season. A peak value in free growing (not cut or grazed) plants, followed by a decline of both responses (weight and tiller number) suggested that mutual shading caused a shift in the carbon balance when lower, shaded leaves became stronger sinks as they aged and became deprived of light by younger, upper leaves. Beheague (1986) associated high yields and growth rates of timothy (*Phleum pratense* L.) with high tiller populations whereas in tall fescue, Wolf et al. (1979) found that practices that stimulate tillering tend to reduce dry matter production per tiller.

### Physiological responses

In order to be productive and persistent, perennial forage grasses must produce new tillers to make up for those that are continuously senescing and dying (Langer, 1956, 1957). In addition to their immediate contribution to forage yield per area, increasing tiller number increases the proportion of the incoming solar radiation that is intercepted by the grass canopy.

Light interception. The importance of light interception in pasture growth was recognized by Watson (1947) and Brougham (1955, 1956). They related light interception by the pasture sward to the amount of leaf area present and were the first to recognize the importance of leaf area index (LAI, the ratio of leaf area to ground area) on the regrowth vigor of pasture plants. Leaf area index relates to photosynthetic recovery and current carbon assimilation and their role in the regrowth process. Leaves in canopies are more light limited than leaves on isolated plants and individual leaves held perpendicular to incident radiation. The degree of limitation increases with LAI and average leaf angle (Loomis and Williams, 1969). Thus, except for leaves at the top of the canopy, most leaves are light limited for most of the time, particularly at lower levels in the canopy since irradiance decreases exponentially as position (height) in the canopy decreases (Ludlow, 1978).

Maximum efficiency of light utilization for leaf net photosynthesis occurs at light intensities of about 10% of full sunlight (Ludlow, 1978), and this is also true for canopy photosynthesis when all leaves are uniformly illuminated at this level. Hay and Walker (1989) explained that in early analysis of crop growth, it was proposed

that crop growth rate was proportional to the fraction of light that was intercepted and reached a ceiling when interception was complete. This became the basis for the development of the concept of optimum LAI ( $LAI_{opt}$ ), at which crop growth rates are maximum and below which growth rate is dependent upon LAI and is less than maximum due to incomplete interception of solar radiation. Above  $LAI_{opt}$  growth rate is depressed due to increased respiratory losses (Brown and Blaser, 1968) and decreased rates of leaf appearance at the bottom of the canopy (Anslow, 1966).

Organic reserves. The accumulation and maintenance of organic reserves, mainly total nonstructural carbohydrates (TNC), in the roots and stem bases of pasture plants has frequently been a declared objective of grazing and cutting practice (Humphreys, 1966). Although carbohydrates (sugars, fructosans, and starches) are the most important reserve compounds, they are in equilibrium with a pool of labile nitrogenous compounds (Smith, 1973; Vickery, 1981). Gallaher and Brown (1977) reported higher TNC concentrations in N-deficient plants of Pensacola bahiagrass compared to those that were well supplied with N, although TNC concentrations in  $C_4$  grasses are, in general, relatively low when compared with that of  $C_3$  grasses (Wilson and Mannetje, 1978; Adjei et al., 1988; Humphreys, 1991). It appears that assimilate can be more readily used in the production of new shoots when N supply is adequate, although Wilson (1975) considers this generalization to be better applicable to  $C_3$  than to  $C_4$  grasses. Gonzalez et al. (1989) showed that regrowth of perennial ryegrass plants growing in an N-starved medium ( $0.2 \text{ mol NH}_4\text{NO}_3 \text{ m}^{-3}$ ) accumulated 2.3-fold more polyfructans in the stubble than plants regrowing in a medium that was not

limiting in N ( $1.0 \text{ mol NH}_4\text{NO}_3 \text{ m}^{-3}$ ). In Coastal bermudagrass fertilized with  $280 \text{ kg N ha}^{-1}$ , Adegbola and McKell (1966) noticed that most of the newly synthesized carbohydrate was retained in the leaves as reducing sugars (glucose and fructose) and that the amount translocated to rhizomes was a small fraction of the total amount synthesized. They also reported that carbohydrate translocation to rhizomes increased as N fertilization rates decreased.

The importance of organic reserves for regrowth following cutting or grazing has been one of the most controversial topics of pasture agronomy. Numerous investigations (Huokuna, 1961; Weinmann, 1961; Alberda, 1966, Dovrat and Cohen, 1970) have shown an association between organic reserve status and the regrowth vigor of swards. Reis et al. (1985) observed a reduction in TNC concentration in roots and stem bases of *Brachiaria decumbens* Stapf. after cutting, and noticed that there were interactions with environment involved in the reduction. When cut soon after the end of the rainy season and without N fertilization, TNC concentrations did not decline, probably due to the lack of optimal conditions for vegetative growth. Working with limpograss, Christiansen et al. (1988) observed lower TNC concentrations in young, actively growing tissue than in old, mature herbage and speculated that active growth demanded greater assimilate supply. The authors also concluded that TNC concentration was indirectly affected by environmental factors because two of the cultivars studied ('Bigalta' and 'Floralta' but not 'Redalta') accumulated shoot TNC at the end of the growing season. Similar effects of environment were seen in switchgrass (*Panicum virgatum* L.) by George et al. (1989).

Although in many cases stored reserves have been positively correlated with regrowth vigor, Humphreys (1991) argues that there is stronger evidence against a close causative relationship. According to him, translocation of assimilate from root or crown tissue for reassembly at the growing points influences growth in a "minor and transitory" fashion. Beaty et al. (1974) studied the translocation of  $^{14}\text{C}$  during regrowth of bahiagrass. When plants were exposed to  $^{14}\text{C}$  and defoliated 48 h later, only about 10% of the  $^{14}\text{C}$  stored in the plant moved to new leaf growth in the following 3 d. In plants harvested at later times, there was a two percentage unit increase in the percentage of total  $^{14}\text{C}$  in leaf growth. Their observations indicated that nearly all of the translocation of reserve materials ceases within 3 to 6 d following complete defoliation. Sampaio et al. (1976), however, demonstrated the importance of organic reserves for bahiagrass tissue maintenance when they observed that even daily removal of all leaf tissue did not kill the stolons until the 13<sup>th</sup> week. Hodgkinson et al. (1985) studied the regrowth of red oatgrass (*Themeda triandra* Forsk.) and indicated that stored TNC would only last for 2 d if it were all used in new growth.

From the evidence in the literature, Humphreys (1991) argues that in most cases the size and the losses from the labile pool of stored carbohydrates are insufficient to account for much regrowth. Shoots normally become photosynthetically independent within 3 d of their exertion and start exporting to other organs, thus shifting from a condition of sink to source of photosynthate. In this scenario, Humphreys (1991) argues that TNC reserves may be regarded only as a

buffer in the system as opposed to a large usable 'pool'. The depletion in TNC reserves from roots, rhizomes, stolons, and stem bases after defoliation is thought to be due more to continued respiration than to mobilization for tissue synthesis (Vickery, 1981). Indeed, this was observed by Steinke (1975) in plants of weeping lovegrass [*Eragrostis curvula* (Schrud.) Nees.] where respiratory demands accounted for a large proportion of TNC lost after defoliation, although there was some export from the stubble to growing shoots.

A possible consensus on the actual role of organic reserves in the regrowth process, seems to reside largely in plant morphology and growth habit. In forage species where grazing or cutting removes a large proportion of total leaf area, organic reserves are likely to be more important than in those species where even close cutting or grazing leaves enough residual leaf area so that regrowth can take place at the expense of current carbon assimilation via photosynthesis.

#### Practical aspects of regrowth physiology: Interplay of reserves and residual leaf area

A solution for the dilemma about the relative importance of residual leaf area and stored reserves seems to lie in the middle ground. Studying the regrowth of orchardgrass plants, Ward and Blaser (1961) concluded that it depended on both the leaf area remaining after defoliation as well as on the carbohydrate reserve level. This dual dependence on TNC and residual LAI was also seen in tropical grass species by Humphreys and Robinson (1966a), who suggested that the two factors interacted in the regrowth of buffel grass (*Cenchrus ciliaris* L.) and green panic (*Panicum maximum* Jacq. var. *trichoglume*). Therefore, although the regrowth of

swards seems to be a two-phased process, the duration of each phase will depend on the level of reserves as well as on the ability of the pasture plant to produce new leaf area (Vickery, 1981).

Despite the variation among pasture species in nature and location of organic reserves and the interactions with other factors such as leaf area, several authors have found a common pattern for the relationship between carbohydrate reserves and growth responses following defoliation. Marshall (1987) suggested that because in pasture plants the leaves are both sources and sinks, defoliation results in a period where growth is limited by the supply of photosynthate (i.e., source limited). Describing the summer growth of a perennial ryegrass sward, Anslow (1965) obtained a linear relationship between herbage mass on pasture and time. This led him to conclude that growth rate, represented by the slope of the line and in this case constant, was not affected by leaf area and its increase with time. Brougham and Glenday (1967) reinterpreted Anslow's data and were able to fit a different growth response curve (sigmoid in shape) where three distinct phases could be identified. A first, exponential phase, showed growth rate increasing with time. The second phase was linear and during this phase the slope (and thus the growth rate) was maximal. The third phase was that of decreasing growth, with the rate eventually equaling zero. This pattern has been confirmed by Harris (1978) who stated that the growth rate of a pasture increases with increasing biomass, provided that this increases photosynthetic capacity by increasing leaf area and interception of incident light. Indeed, this was precisely what had been postulated by Brougham (1955, 1956). He theorized that the

linear portion of the growth curve related to the period (sometimes rather short) during which the positive carbon balance (i.e., photosynthesis exceeding respiration) of the sward was maximum. In this situation, which Brougham called optimum LAI ( $LAI_{opt}$ ), the lowermost leaves of the canopy are at, or slightly above, their light compensation point (the compensation point being the light intensity at which  $CO_2$  uptake by photosynthesis equals  $CO_2$  evolution due to respiration). Above  $LAI_{opt}$ , lower leaves would become 'parasitic' shifting their carbon balance and causing a reduction in growth rate and this was what happened in the third phase of the growth curve described by Brougham and Glenday (1967).

If the concept of  $LAI_{opt}$  is assumed to be valid, control of LAI at an optimum is probably most practical in monospecific pastures when subjected to light and frequent defoliation (Vickery, 1981). This type of defoliation, however, has rarely maximized growth rates because it is the younger leaves that are usually removed by either cutting or grazing as they are invariably at the top of the canopy. These top leaves have been shown to be the most photosynthetically active and thus the most efficient in promoting further shoot growth (Begg and Wright, 1964; Brown et al., 1966; Jewiss and Woledge, 1967; Woledge, 1971, 1978). This probably explains why lenient grazing managements do not produce growth rates as high as intensive grazings, as shown by Brougham (1959) and Bryant and Blaser (1961). Reduction in seasonal HA with more frequent and intense defoliation, as it has been shown in the literature (Jameson, 1963; Campbell, 1969; Harris, 1978), may be wholly or partially

compensated for by improved utilization, i.e., by reduced losses of unharvested herbage (Korte and Harris, 1987).

The literature shows little agreement on any optimum grazing or clipping management for a particular pasture system. Undoubtedly, the reason for this lack of agreement is the complex nature of the problem, as the interactions within the pasture ecosystem are numerous. With regard to  $LAI_{opt}$  for example, there may be situations where the concept does not seem to apply. While some crops may clearly reach an optimum LAI over a specific growth period, others may not. Particular combinations of environmental factors may shift  $LAI_{opt}$  to levels far above those which the plant community is capable of supporting (Vickery, 1981). For example, in many areas where the level of incident radiation is high, it may not limit plant growth and an optimum LAI may not be found.

#### Animal Responses to the Grazed Pasture

The effects of grazing animals on pastures have been reviewed extensively (Spedding, 1965; Morris, 1969; Tainton, 1974; Watkin and Clements, 1978; Snaydon, 1981; Parsons et al., 1983a, b; Matches, 1992) and it is accepted that animals affect pastures in three major ways: defoliation, trampling, and excretion. Considering however, that the productivity of an area of grassland is, in most cases, assessed in terms of animal products (Humphreys, 1966) it is important to understand how grazing animals respond to forage plants and their management.

Pasture attributes which determine the level of animal production and that are commonly modified by management practices usually relate to pasture availability, the

structure of the sward, and the nutritive value and quality of the pasture and its components. According to Humphreys (1991), the effects of management on the rate of pasture growth and on progress to flowering affect mineral concentration and the organization of carbohydrates into cell contents, cell wall constituents, and cell wall type. The rate of plant removal decides what material is available for senescence and the presence of senescing material is a major constraint to nutritive value. The stage and season of forage use strongly influence the relative proportions of plant parts (e.g., leaf vs. stem). The level of feed availability, as modified by the intensity of previous use, determines the opportunity for diet selection.

Humphreys (1991) discussed animal responses to pastures under three main headings: pasture quality, sward structure, and grazing behavior and selectivity.

#### Pasture quality

Quality of pasture, or forage quality, is a concept that integrates biotic and abiotic factors (Moore, 1980, 1994). Mott (1959) proposed that differences in forage quality are best expressed as differences in animal performance (e.g., daily gain or milk production) when animal potential is not limiting, forage or pasture availability allows for ad libitum intake, and no other sources of energy or protein are provided. Digestibility and intake of energy, N concentration, minerals and vitamins, and the possible occurrence of toxicities and imbalances (i.e., anti quality factors) are aspects that relate to forage quality. Because a shortage of digestible energy (DE), due to limitations in intake, is the most common constraint to forage quality in warm-season grasses (Romero and Siebert, 1980), it will be the main focus of this discussion.

Young pasture growth usually leads to higher organic matter digestibility and intake than pasture that is reserved from grazing. This decrease in nutritive value is a phenomenon observed in both C<sub>3</sub> and C<sub>4</sub> forage species, but is of particular interest in warm climates, especially the tropics (Nascimento and Pinheiro, 1975; Nada and Jones, 1982; Pond et al., 1987). Moore et al. (1971) showed a decline in concentration of IVDOM from 599 to 432 g kg<sup>-1</sup> in bahiagrass hay when age at cutting increased from 6 to 14 wk. Nitrogen concentration also declined between the two ages from 12.2 to 10.1 g kg<sup>-1</sup> whereas acid detergent fiber (ADF) and lignin concentrations increased from 409 to 453 and from 37 to 54 g kg<sup>-1</sup>, respectively.

Humphreys (1991) draws two main conclusions from what is described above. The first, which bears on management practices, is that animals whenever possible, should be given maximum access to young pasture growth. He argues that this may be an explanation of why schemes of rotational stocking often fail to increase animal performance when compared with continuous stocking. It also suggests that rotational stocking with long rest intervals is more deleterious to animal production than when the rest intervals are short (here an analogy can be made between rotational stocking and hay harvesting schedules in terms of regrowth intervals). The second conclusion is that slow rate of decline in pasture quality with age can be a decisive criterion for choosing which pasture species to plant. Norton (1982) verified that, in general, this rate of decline is greater for plants with high digestibility although for any one level of digestibility there is considerable variation in the rate of decline.

The relative contributions of intake and digestibility to animal performance are not the same, with intake contributing about 60 to 90% and digestibility 10 to 40% (Mertens, 1994). Minson (1971) stated that there is greater opportunity to choose pasture species and cultivars with higher intrinsic intake characteristics than to select plants with higher digestibility. One of the characteristics that is known to increase intake in pastures is leafiness, although this usually applies more to comparisons within species than to comparisons between species (Minson and Laredo, 1972; Minson and Bray, 1986). In addition, Hodgson (1990) points out that sward height and bulk density also affect intake, although to variable degrees depending on animal species.

It may be rationalized that the greater intake of leaves is related to their shorter retention times in the rumen, since leaf tissue is, in many but not all cases, more easily degraded than stem tissue. Although an essay on intake control mechanisms in forage-fed ruminants is not intended here, it seems reasonable to work under the assumption that the distention mechanism (i.e., the physical capacity of the rumen as a limitation to intake until forage particles are broken down and are able to pass from the rumen) is what controls intake of grazing animals, at least when forage quantity is not limiting intake (Fisher et al., 1995).

#### Sward structure and grazing behavior

Because sward structure and grazing behavior interact strongly they will be discussed simultaneously. Intake is a key component of forage quality, so there is a need to understand the ways in which animal intake (and ultimately, production) is

influenced by the relative proportion and arrangement of plant parts in the pasture sward. First, it is important to bear in mind that, in general, animals graze from the upper layers of the sward canopy and have a strong preference for green leaves (Fisher et al., 1995). In fact, Arnold (1981) pointed out that due to selectivity the composition of the diet of a grazing animal may be quite unrelated to the proportions of the various plant species or plant parts present on the pasture. In other words, given the opportunity animals will graze selectively. Detailed reviews on this subject have been published (e.g., Arnold and Hill, 1972) but in general, leaf is preferred over stem, and green, young material is preferred over dead plant parts. The material eaten usually has a higher concentration of N, P, and digestible energy and is lower in fiber (Arnold, 1981). Wilson and Minson (1980) reported that in many cases stem is eaten in much smaller quantities than leaves, even when at the same digestibility.

In terms of plant part proportion, warm temperatures tend to accentuate the problem of lower intake of stem because they promote stem elongation and its lignification (Henderson and Robinson, 1982a, b). In addition, the detrimental effects of stem to forage quality are greater in most  $C_4$  grasses because, unlike temperate grasses, the tropical grasses have no specific environmental requirements for flowering, and reproductive shoot elongation happens continuously over the growing season. Temperate  $C_3$  grasses not only have higher leaf/stem ratios (Minson and Wilson, 1980) but less vascular tissue (Wilson and Hattersley, 1983) which is less digestible than other cell types such as parenchyma.

In addition to plant part composition and the presence of dead material, other factors influence the structure of the grass sward, grazing behavior, and intake. Canopy height and sward bulk density affect ease of prehension and in practice relate to herbage mass (HM) and herbage allowance (HAL). Redmon et al. (1995) reported a severe decrease in intake of wheat (*Triticum aestivum* L. var. Chisholm) as HAL fell below 20 to 24 kg DM (kg BW)<sup>-1</sup> d<sup>-1</sup>. In a study where calves and lambs grazed perennial ryegrass cv. S23, Jamieson and Hodgson (1979) observed that as the green HM was progressively reduced from 3000 to 1000 kg OM ha<sup>-1</sup>, biting rate and grazing time increased, but not sufficiently to offset the rapid decline in bite weight. As a result of declining HM from 3000 to 1000 kg OM ha<sup>-1</sup>, intake was reduced by 24 and 39% for calves and lambs, respectively. The same authors (Hodgson and Jamieson, 1981) reported that adult cattle are better able to compensate for changing sward conditions by increasing herbage intake (mainly by increasing grazing time and biting rate) than young calves that are inexperienced grazers. Increases in grazing time and decreases in bite weight with advancing stages of defoliation were also observed by Chacon and Stobbs (1976) in cattle grazing *Setaria anceps* Stapf. ex Massey cv. Kazungula. These authors concluded that leaf is the most important component of the sward and that leaf yield, percentage leaf, and bulk density of green material (leaf and stem) are the major sward factors influencing intake by grazing animals.

Chacon et al. (1978) found that unfavorable sward conditions, mainly low HM, kept Hereford steers from satisfying their feed requirements when grazing *S.*

*anceps* cv. Nandi and Pangola digitgrass at high stocking rates (8 head ha<sup>-1</sup>). Intake was low despite long grazing times that attempted to compensate for low bite weight. Similar observations on the influence of decreased leaf percentage, decreased HAL, and decreased sward height on the grazing behavior, intake, and performance of grazing animals have been made by Mannetje and Ebersohn (1980), Hodgson (1981), Ludlow et al. (1982), Wright and Whyte (1989), Roth et al. (1990), Burlison et al. (1991), Penning et al. (1991), Chestnutt (1992), Laca et al. (1992), and Penning et al. (1994).

#### Bermudagrass: Origin, Distribution, and Status as a Forage Crop

The Gramineae is one of the largest plant families and contains more than 600 genera (Leafe, 1988). All of the cultivated temperate grasses are in the subfamily Pooideae, whereas Panicoideae and Chloridoideae contain most of the tropical grasses. The other three subfamilies within Gramineae are Bambusoideae, Centothecoideae, and Arundinoideae (Clayton and Renvoize, 1992).

Renvoize and Clayton (1992) explained that the evolutionary course of Gramineae has been in three main directions: 1) from an unspecialized ancestor of forest margins the bamboos found adaptation to forest environments; 2) cool-temperate open steppe and meadows were favored by the poooids; and 3) open savannas and semi-arid regions of the tropics became the ideal environments for chloridoids and panicoids.

## Origin

The genus *Cynodon* is a small, systematically distinct group in the Chloridoideae. Harlan et al. (1970a) grouped eight species of *Cynodon* according to their geographical distribution. Most of the species studied, including *C. dactylon* (L.) Pers., *C. nlemfuënsis* Vanderyst, *C. plectostachyus* (K. Schum.), and *C. aethiopicus* Clayton et Harlan, find widespread distribution over eastern tropical and sometimes subtropical Africa. *Cynodon incompletus* Nees. and *C. transvaalensis* Burt-Davy were found in South Africa whereas *C. arcuatus* J.S. Presl ex C.B. Presl and *C. barbieri* Rang et Tad (the latter two being completely isolated genetically from each other and from other species in the genus) predominate in South Asia and South Pacific Islands. Clayton and Harlan (1970) wrote a key to the tropical African species of *Cynodon* and used the presence of underground rhizomes as a key distinguishing characteristic, separating *C. dactylon* (with rhizomes) from *C. plectostachyus*, *C. aethiopicus*, and *C. nlemfuënsis* (without rhizomes). Within *C. dactylon*, however, there is still a great deal of variation. Harlan and de Wet (1969) recognized six botanical varieties within the species and grouped them according to geographic distribution. Varieties *elegans* and *polevansii* are fairly abundant over southeastern Africa, south of 10° S latitude. Variety *coursii* predominates in Madagascar, off the southeastern African coast. Variety *aridus* is found between the latitudes of 15° S and 35° N, from southeastern Africa to northeastern Egypt and southern Israel (although not very abundant there), plus the north and north central

regions of India. Variety *polevansii* has been found only at one location in South Africa whereas var. *afghanicus* accessions are all from Afghanistan.

In contrast with the varieties described above, var. *dactylon* "enjoys remarkable distribution" (Harlan and de Wet, 1969), not only in Africa and Asia but in all other continents except Antarctica. Specimens have been found in northern latitudes as far north as Siberia (53° N). However, while the distribution is truly cosmopolitan, Harlan and de Wet (1969) warned that one should not imagine vast areas of pure stands of var. *dactylon*, except under the most artificial conditions. The variety thrives only under extreme disturbance and does not invade natural grasslands or forest vegetation.

*Cynodon dactylon* var. *dactylon* is the cosmopolitan weed, forage, and turfgrass so widely distributed in the warmer areas of the world (Harlan, 1970; Harlan et al., 1970c), although, besides the Tropical race, there are Temperate and Seleucidus races, both very winterhardy and well adapted to northern latitudes (Harlan and de Wet, 1969). The Seleucidus race was so named because its center of distribution corresponds to the region of the original Seleucid empire (Pakistan to Turkey) (Harlan et al., 1970b). Harlan and de Wet (1969) stated that typical, well-developed specimens of Seleucidus stand out conspicuously from typical specimens of Tropical and Temperate races. Seleucidus plants are strikingly coarse, vigorous, bluish in color, somewhat hairy, and strongly winter-hardy. It is especially aggressive in fertile soils and its prostrate stems seem to "gallop", emerging from the soil as stolons and then turning back down as rhizomes (Harlan and de Wet, 1969;

Harlan et al., 1970b). The best examples of Seleucidus come from Afghanistan, Iran, Iraq, and Turkey. The vigor, hardiness, and productivity of the race make it especially valuable for grazing and hay production, as opposed to the Tropical and Temperate races, which are usually smaller ( $< 20$  cm tall) and turf forming.

### Introduction and Cultivar Development

According to Harlan (1970) there is no record of the first introduction of bermudagrass into the US, but he believes it probably happened by the mid-18<sup>th</sup> century or perhaps earlier. Burton and Hanna [1995; citing Mease (1807), Howard (1881), and Tracy (1917)] did, however, trace the earliest records of the introduction of bermudagrass into the US. They mentioned the diary of Thomas Spalding, owner of Sapelo Island, Georgia, who wrote: "Bermudagrass was brought to Savannah in 1751 by Governor Henry Ellis. If ever this becomes a grazing country, it must be through the instrumentality of this grass". Harlan (1970) stated that despite a number of early enthusiastic supporters, bermudagrass had the reputation of being a vicious weed. Most southern farmers interested in growing cotton and corn (*Zea mays* L.) were trying to destroy the grass (Burton and Hanna, 1995). The rhizomes were easily spread by the horse- or mule-drawn equipment and an established turf was almost impossible to plow out with the same equipment (Harlan, 1970).

In general, the attitude towards bermudagrass among southern farmers did not change until the development and release of cv. Coastal (Burton, 1943; cited by Harlan, 1970). Coastal is the result of a cross between a local Georgia cotton-patch strain and an introduction from South Africa. The African introduction has since

been lost and can no longer be identified but its well-developed rhizomes suggest that it must have been some race or variety of *C. dactylon* (Harlan, 1970). The fact that Coastal is "a tetraploid, forming an open sod with bluish ascending leaves, slender, straight, somewhat sparse rhizomes, and modest winterhardiness suggests that the other parent was a collection of *C. dactylon* var. *elegans*" (Harlan, 1970). In plot tests, Coastal yielded twice as much as common bermudagrass and was superior to either parent although it failed to produce seed (Burton, 1989).

The development of Coastal bermudagrass can be considered a landmark, not only in forage and livestock development in the southeastern US, but also in the science of plant breeding. Contrary to common bermudagrass, Coastal is not a weed although its acceptance was initially low due to prejudice and the need for vegetative propagation (Harlan, 1970; Burton, 1989). However, lack of seed production together with its rhizomes not being especially pernicious were the very traits that made Coastal no longer a pest because it could now be more easily destroyed.

In addition to breeding and selection for agronomic traits, other genetically controlled characteristics such as digestibility, have served as selection criteria. 'Coastcross-1', an  $F_1$  hybrid between Coastal and a highly digestible introduction from Kenya, is an example. Coastcross-1 was shown to be an average of 12.3% more digestible and as much as 160% higher yielding than Coastal (Burton, 1947; Burton et al., 1967). According to Harlan (1970), these combined developments resulted in something like a revolution in the livestock industry of the southern US. The timing was especially opportune since the one-crop cotton economy was declining

rapidly. Research on the forage potential of bermudagrass intensified as there was need to evaluate it, learn how to manage it, and if possible, improve it. Harlan stated that "more important, perhaps, was a revolution in the attitude of farmers toward bermudagrass and a revelation to plant breeders concerning the potential of genetic improvement". Both, he argued, would have far-reaching consequences.

Coastal was widely distributed and considerable area was planted. Soon, new hybrids were developed, especially out of G.W. Burton's breeding program at Tifton, Georgia. Across the Southeast new hybrids were released to fit the specificities of regional climate and soil types. 'Suwannee' (Burton, 1962), 'Coastcross-1' (Burton, 1972), and 'Tifton 44' (Burton and Monson, 1978) are some of the hybrids that came out of the Tifton program. For cooler areas of the upper South and lower Midwest, 'Midland' bermudagrass was released, extending the range of the grass to south Kansas, Kentucky, and Maryland (Decker, 1959; cited by Harlan, 1970). 'Greenfield' (Elder, 1955; cited by Harlan, 1970), 'Hardie' (Taliaferro and Richardson, 1980a), and 'Oklan' (Taliaferro and Richardson, 1980b) were developed for Oklahoma conditions. In Louisiana, 'Grazer' (Eichhorn et al., 1985a) and 'Brazos' (Eichhorn et al., 1985b) were released with Grazer being recommended for pasture more than for hay production whereas Brazos serves both purposes well. Germplasm Brazos-R3 (Crougham et al., 1994) was developed through tissue culture of Brazos stolon tissue and released due to its increased resistance to fall armyworm [*Spodoptera frugiperda* (J.E. Smith)] and to the active metabolite of the fungus *Bipolaris cynodontis* (Marignoni) Shoemaker. In addition, Brazos-R3 has high forage

yield and nutritive value. Other cultivars such as Callie (a selection from *C. dactylon* var. *aridus*) and Alicia (selected from *C. dactylon* var. *elegans*), both susceptible to cold and to rust (*Puccinia cynodontis* Lac. ex Desmaz), are used to varying degrees in the South (Burton and Hanna, 1995).

More recently, three new cultivars have been added to the Tifton series. 'Tifton 68', despite being *C. nlemfuensis*, is considered by Burton and Monson (1984) to be a bermudagrass. It is a vigorous, highly digestible, non-rhizomatous F<sub>1</sub> hybrid from a cross between the two most digestible plant introductions in the collection at Tifton. 'Tifton 78', the best F<sub>1</sub> hybrid between Tifton 44 (male parent) and Callie (female parent), was released due to its vigor, fast spreading, easy establishment, and early spring growth at the Tifton location (South Georgia) (Burton and Monson, 1988).

The latest *Cynodon* release from G.W. Burton's program is 'Tifton 85', the best F<sub>1</sub> hybrid between a South African introduction and Tifton 68. It is described by Burton et al. (1993) as being taller, with larger stems, broader leaves, and darker green color than other bermudagrass hybrids. Compared with Coastal, Tifton 85 yielded 26% more dry matter, was 11% more digestible, and more succulent (lower dry matter concentration in the fresh herbage) at harvest (Burton et al., 1993). Tifton 85 has outyielded Tifton 68 in clipped-plot trials (18.6 vs. 15.2 Mg DM ha<sup>-1</sup> yr<sup>-1</sup>, mean of 3 yr) although in vitro dry matter digestibility (IVDMD) was higher in Tifton 68 (636 g kg<sup>-1</sup> vs. 603 g kg<sup>-1</sup>) (Hill et al., 1993). In the same trial, Coastal yielded an average 15.5 Mg DM ha<sup>-1</sup> yr<sup>-1</sup> with mean IVDMD of 543 g kg<sup>-1</sup>.

### Cynodon Forages in Florida

Two major species of *Cynodon* are grown for forage in Florida either as grazed pasture or as hay crops. In North Florida, bermudagrasses are generally well adapted and capable of surviving the moderately cold winters. Between the 29° N and 28° N parallels, lies what can be called a transition zone, south of which the non-rhizomatous stargrasses (*C. nlemfuensis* var. *nlemfuensis* and *C. aethiopicus*) are best adapted since cold fronts reaching South Florida in the winter are weaker and not usually a serious threat to these cold susceptible grasses.

Harlan (1970) described two varieties of stargrass. Variety *robustus* is characterized by large, robust plants with long, slender racemes. Plants of var. *nlemfuensis* tend to be finer, less robust, with shorter racemes and able to tolerate more heat and drought than those of var. *robustus*. Besides these morphological differences, the two varieties are genetically distinct (Harlan et al., 1970d), although intermediate types have been found that cross readily with both botanical varieties (Harlan, 1970). The center of distribution of stargrass corresponds to tropical eastern Africa (mainly Kenya, Tanzania, and Uganda) and Angola in west Africa.

Four major stargrass cultivars are grown in South and South Central Florida. These are 'Ona', 'McCaleb', 'Florico', and 'Florona'. McCaleb stargrass (*C. aethiopicus* Clayton et Harlan) was selected from 39 South African introductions for its vigor and rate of stolon growth (Hodges et al., 1975). Ona stargrass was selected from 39 introductions from Zimbabwe due to its vigor and competitiveness (Hodges et al., 1984; Alderson and Sharp, 1994). Both McCaleb and Ona stargrasses are still in

use in south Florida but are no longer recommended by the Florida Agricultural Experiment Station for new plantings (P. Mislevy, personal communication).

The two latest stargrass releases are 'Florico' and 'Florona' (Mislevy et al., 1989a, b). Florico was introduced into Puerto Rico from Kenya in 1957, and brought to Florida from Puerto Rico in 1972. Cultivar registration was received in 1993 (Mislevy et al., 1993a). Florona, a more persistent cultivar than Ona and Florico was first observed in a Pensacola bahiagrass pasture at the Range Cattle Research and Education Center in Ona, FL, in 1974 (Mislevy et al., 1989b). It was multiplied and entered evaluation in 1975 receiving cultivar registration in 1993 (Mislevy et al., 1993b). Both Florico and Florona are well adapted to South Florida flatwoods either as grazed pasture or hay crops. Both grasses lack winterhardiness and are not recommended for areas north of the transition zone described earlier (i.e., north of 28° N).

Several bermudagrasses are used in South Florida including Suwannee, Callie, and Coastal. 'Florakirk' is the newest cultivar and was released by the Florida Agricultural Experiment Station (Mislevy et al., 1995). Like Tifton 78, Florakirk is an F<sub>1</sub> hybrid between Tifton 44 and Callie but with reversed parentage (i.e., in Florakirk, Callie is the male parent and Tifton 44 is the female parent). Florakirk has been evaluated in Florida since 1978 as Tifton 35-3, Callie hybrid 35-3, or simply 35-3. At Tifton, however, line 35-4 performed better and was released as Tifton 78 (Burton and Monson, 1988). In Florida, Florakirk has shown good persistence, productivity, and quality, besides unusual (for a bermudagrass) tolerance to poorly

drained areas. In Jay, FL, Florakirk outyielded Tifton 78 and Tifton 44 in plots harvested every 4 wk with the three grasses averaging 12.8, 7.2, and 6.3 Mg ha<sup>-1</sup> yr<sup>-1</sup> over 6 yr (Mislevy et al., 1995). Florakirk also showed equal or better cold tolerance than the other grasses. In Quincy, FL, Florakirk showed fast establishment after an August 1986 planting, covering 65% of the ground in 2 mo. In the same time period, Alicia covered 40%, Grazer 15%, Callie 10%, and Coastal 6% (Mislevy et al., 1995). In a 2-yr clipping study in Gainesville, FL, Florakirk (14.6 Mg ha<sup>-1</sup> yr<sup>-1</sup>) outyielded Coastal (13.4 Mg ha<sup>-1</sup> yr<sup>-1</sup>) and Tifton 78 (11.0 Mg ha<sup>-1</sup> yr<sup>-1</sup>). Crude protein concentrations were similar in the three grasses (avg. 116 g kg<sup>-1</sup>) but concentration of in vitro digestible organic matter (IVDOM) was higher in Florakirk (610 g kg<sup>-1</sup>) than in Coastal (530 g kg<sup>-1</sup>) and Tifton 44 (560 g kg<sup>-1</sup>) (Ruelke, 1990; cited by Mislevy et al., 1995).

Performance of Florakirk under grazing at Ona has been similar or better than most commercial bermudagrass cultivars. In a mob-grazing study, Florakirk plus six other *Cynodon* entries were grazed every 2, 4, 5, or 7 wk for 2 yr. Florakirk had higher herbage accumulation (15.7 Mg ha<sup>-1</sup> yr<sup>-1</sup>) than the other five bermudagrasses (Tifton 44 [9.4], Tifton 72-81 [14.6], Grazer [7.6], and Tifton 68 [12.3]) and two stargrasses (Florico [15.4] and Florona [12.5]) (Mislevy et al., 1995). In the same study, concentrations of CP and IVDOM in Florakirk herbage were 77 and 513 g kg<sup>-1</sup>, respectively. These values were similar or no more than 20 and 14% lower (for CP and IVDOM, respectively) than the other grass entries.

Data on the performance of cattle grazing Florakirk bermudagrass are limited. Mislevy et al. (1995) reported on a study where animal performance was measured on Florakirk and Brazos bermudagrasses using different pasture rotations (1 wk grazing and 4 wk rest or 2 wk grazing and 4 wk rest). Weekly rotation increased cattle average daily gain (ADG) and gain  $\text{ha}^{-1}$ , more so in Brazos than in Florakirk. Mean ADG across the two rotation treatments over 2 yr of the study were 0.28 and 0.38 kg, whereas gains  $\text{ha}^{-1}$  were 414 and 403 kg for Florakirk and Brazos, respectively. Larbi et al. (1989) compared performance of beef steers grazing Florakirk with those grazing Florico and Florona stargrasses. Management included rotational grazing (2 wk grazing and 4 wk rest) and variable (put-and-take) stocking rate so that herbage allowance was kept similar in the three grass treatments and differences in animal performance reflected differences in forage quality. The 2-yr averages of ADG, gain  $\text{ha}^{-1}$ , and carrying capacity were: 0.55, 0.43, and 0.39 kg animal $^{-1}$ ; 812, 667, 541 kg  $\text{ha}^{-1}$ ; and 1481, 1575, and 1358 steer days  $\text{ha}^{-1}$  for Florico, Florona, and Florakirk, respectively. The authors concluded that differences in forage quantity (avg. of 4.9 Mg  $\text{ha}^{-1}$  of forage available for the stargrasses and 3.6 Mg  $\text{ha}^{-1}$  for Florakirk) partially accounted for the comparatively low animal production on Florakirk and this was reflected in its lower carrying capacity. In this study at Ona, the stargrasses gave better animal performance than Florakirk.

Evaluation of Tifton 85 in Florida has been underway for only a few years. There are no reports of comparative grazing evaluation of Florakirk and Tifton 85 in the literature. Because plant and animal performance on grazed pastures interact

strongly with the environment, there is a need to assess the potential of these two new bermudagrass cultivars in North Central Florida. The adoption of these improved forage grasses could have an impact on the economics of production of the beef cattle industry in the state. This research was designed to quantify pasture and animal responses of yearling beef heifers grazing Florakirk and Tifton 85 bermudagrasses and to assess their potential as grazed pastures for cow-calf systems. It is expected that results will be useful to the livestock industry and in helping to devise optimum grazing management practices for Florakirk bermudagrass in North Central Florida.

### CHAPTER 3

## PRODUCTIVITY AND NUTRITIVE VALUE OF 'FLORAKIRK' BERMUDAGRASS PASTURES AS AFFECTED BY GRAZING MANAGEMENT

### Introduction

The beef cattle industry is one of the most important agricultural enterprises in the southeastern US. In Florida, beef cow-calf operations accounted for 31% of the total cash receipts from livestock marketing in 1993, an increase of \$19 million from 1992 (Florida Agricultural Statistics, 1994). Warm-season perennial grasses are the backbone of these cow-calf operations. Species most used on grazed permanent pastures include bahiagrass (*Paspalum notatum* Flügge), limpograss [*Hemarthria altissima* (Poir.) Stapf. et C.E. Hubb.], stargrass (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis* and *C. aethiopicus* Clayton et Harlan), and bermudagrass [*Cynodon dactylon* (L.) Pers.]. The livestock industry in Florida could benefit from the development and introduction of improved warm-season grasses that are productive and of high nutritive value under grazing, and that can give greater beef production per unit land area than the cultivars currently in use. There is a need, however, to evaluate these new grasses under grazing so that optimal management strategies which maximize grass persistence, productivity, and nutritive value can be devised.

'Florakirk' bermudagrass was developed by G.W. Burton at the Coastal Plain Experiment Station (USDA-ARS and University of Georgia) in Tifton, GA (Mislevy

et al., 1995). It has been evaluated under clipping and grazing in South Central Florida since 1979 and was released by the Florida Agricultural Experiment Station in 1994 (Mislevy et al., 1995). Florakirk is one of a number of  $F_1$  hybrids between 'Callie' and 'Tifton 44' bermudagrasses. It entered the evaluation program at the University of Florida Range Cattle Research and Education Center at Ona, FL, as experimental line 35-3 (sometimes called Tifton 35-3 or Callie hybrid 35-3). Another hybrid from the same cross was evaluated as line 35-4 and released by the Coastal Plain Experiment Station as 'Tifton 78' (Burton and Monson, 1988) because it showed the best performance at the Tifton location (Sollenberger et al., 1995).

Despite finding some use in Georgia, Tifton 78 has not adapted well to the Florida environment. Adjei et al. (1989) compared two bahiagrasses, three limpograsses, and three bermudagrasses (including Florakirk and Tifton 78) in a study where pastures were mob-grazed to approximately 6 cm every 2, 4, 6, or 8 wk. The authors reported poor performance of Tifton 78 and concluded that it was related to its slow establishment. This resulted in low seasonal herbage accumulation (HAC) ( $8.7 \text{ Mg DM ha}^{-1}$ ) and poor competitiveness against common bermudagrass during the establishment phase. In the same study, HAC of Florakirk was  $11.9 \text{ Mg DM ha}^{-1}$  (same as that of 'Pensacola' bahiagrass) and 'Floralta' limpograss was the highest yielding entry ( $16.8 \text{ Mg DM ha}^{-1}$ ). Concentration of crude protein (CP) in Florakirk herbage sampled pregraze (152, 100, 91, and  $69 \text{ g kg}^{-1}$  when grazed every 2, 4, 6, and 8 wk, respectively) was similar to or greater than that of the other grasses within a grazing frequency. In vitro digestible organic matter (IVDOM) concentration (630,

560, 520, and 440 g kg<sup>-1</sup>, for the same grazing frequencies, respectively) of Florakirk was similar to that of Tifton 78 at all grazing frequencies, but Florakirk IVDOM showed the steepest decline of all grasses tested as grazing frequency decreased from 2 to 8 wk. A similar trend was observed by Mislevy et al. (1988).

In several locations in North and North Central Florida, Florakirk has been compared with commercial bermudagrass cultivars including 'Coastal', 'Coastcross-1', 'Alicia', and Tifton 44 under clipping management (Mislevy et al., 1995). Productivity and nutritive value responses were equal to or better than those of the other cultivars in most cases. Data are lacking, however, on the responses of Florakirk to grazing management in North and North Central Florida.

Research was initiated at Gainesville in order to assess the performance of Florakirk bermudagrass pastures under a wide range of grazing management practices. Specific objectives were to 1) measure seasonal HAC and 2) determine forage nutritive value of Florakirk pastures grazed at different intervals and to different stubble heights.

### Materials and Methods

The trial was conducted at the Forage Evaluation Field Laboratory, located within the University of Florida Beef Research Unit, 18 km northeast of Gainesville, FL (30° N lat.) Data were collected during the 1993 and 1994 grazing seasons and monthly rainfall totals for these years are shown in Table 3.1. The soil at the research site is a Pomona sand (sandy, siliceous, hyperthermic Ultic Haplaquod),

Table 3.1. Monthly rainfall totals in 1993 and 1994 at the Beef Research Unit, 18 km northeast of Gainesville, FL.

| Month | Year           |      | 84-yr average <sup>†</sup> |
|-------|----------------|------|----------------------------|
|       | 1993           | 1994 |                            |
|       | ----- mm ----- |      |                            |
| Jan.  | 92             | 226  | 78                         |
| Feb.  | 109            | 16   | 87                         |
| Mar.  | 103            | 88   | 92                         |
| Apr.  | 49             | 33   | 75                         |
| May   | 55             | 90   | 91                         |
| June  | 102            | 166  | 168                        |
| July  | 108            | 134  | 180                        |
| Aug.  | 142            | 99   | 185                        |
| Sep.  | 56             | 111  | 137                        |
| Oct.  | 117            | 142  | 73                         |
| Nov.  | 124            | 34   | 49                         |
| Dec.  | 65             | 41   | 77                         |
| Total | 1122           | 1180 | 1292                       |

<sup>†</sup> Average was recorded at the Univ. of Florida Agronomy Farm in Gainesville, FL.

one of several Spodosols that in this region are collectively referred to flatwoods soils. Spodosols in this region are typically low in fertility with moderate to poor drainage. They have an impermeable layer (hardpan) about 50 cm below the soil surface, and during the summer rainy season, standing water is common.

### Pasture Establishment

A 1-ha pasture of Florakirk bermudagrass was established on 13 July 1992 from freshly-cut, mature, well-fertilized stem cuttings. Plant material was broadcast on well tilled soil and cut in immediately. The soil was firmly packed, and irrigation equivalent to 13 mm of rainfall was applied. On 20 July, the pasture was sprayed with 2,4-D [(2,4-dichlorophenoxy) acetic acid] at 1 kg a.i. ha<sup>-1</sup> and fertilized with 36, 16, and 30 kg ha<sup>-1</sup> of N, P, and K, respectively. Another 13 mm of irrigation water were applied on 27 July, and N was applied at 56 kg ha<sup>-1</sup> as NH<sub>4</sub>NO<sub>3</sub> on 27 August. On 21 September, the pasture received a second application of 2,4-D, at the same rate as the first, and on 23 September another 56 kg N ha<sup>-1</sup>. The pasture was not grazed or cut in the year of establishment.

Average (1993 and 1994) soil pH was 5.5, and Mehlich I extractable P, K, Mg, and Ca concentrations were 4, 6, 36, and 372 mg kg<sup>-1</sup>, respectively. The pasture was burned on 13 Mar. 1993, and fertilized with 45, 20, and 74 kg ha<sup>-1</sup> of N, P, and K, respectively, on 20 April. Another 56 kg N ha<sup>-1</sup> was applied on 2 June. The 1-ha pasture was divided in half and 0.5 ha were used for the trial. This area was further divided using electric fence into 18 paddocks measuring 10 by 20 m, with a 5-m wide lane surrounding the entire experimental area.

### Experimental Design and Grazing Management

Responses of plants to grazing were measured using a mob-grazing technique (Mislevy et al., 1983) with paddocks being the experimental units. Treatments included all possible combinations of three grazing cycles (GC; 7, 21, and 35 d) and

three postgraze stubble heights (SH; 8, 16, and 24 cm) and were arranged in a randomized complete block design with two replications. A grazing cycle consisted of a grazing period (as short as 1 h at times, and rarely longer than 10 h) plus a rest period between grazings. Each year, grazing commenced when average sward height was approximately 16 cm above the assigned SH. A group of about 12 crossbred (*Bos taurus* × *B. indicus*) yearling beef heifers was led to a paddock and grazing was monitored until SH was reached (mean of 15 height measurements) and the animals removed. Stocking densities were adjusted according to animal availability and to the amount of forage to be grazed.

The entire area received 56 kg N ha<sup>-1</sup> as NH<sub>4</sub>NO<sub>3</sub> on 21 July and again on 1 Sep. 1993. Fifty mm of irrigation water were applied on 11 August, and 25 mm on 18 Aug. 1993 because rainfall had been well below average during the entire spring and summer periods (Table 3.1). Before grazing started in 1994, the entire area was mowed to 10 cm to remove the grass that had been killed by frost the previous winter. On 31 Mar. 1994, 2,4-D was applied at a rate of 1 kg a.i. ha<sup>-1</sup>. Fertilization with 45, 20, and 74 kg ha<sup>-1</sup> of N, P, and K, respectively, was done on 6 April. Nitrogen was applied at 56 kg ha<sup>-1</sup> as NH<sub>4</sub>NO<sub>3</sub> on 11 May, 13 July, and 23 August. The grazing seasons were from 14 June to 11 Oct. 1993 (126 d) and from 16 May to 17 Oct. 1994 (161 d).

### Pasture Sampling

In each grazing cycle, for each paddock, herbage mass (HM) above soil level was determined pre- and postgraze using a double sampling technique. At each

sampling, in each paddock, four 0.25-m<sup>2</sup> sites representing the range of HM (from lowest to highest) were selected and measured with a disk meter (Santillan et al., 1979). The herbage at the four sites was then clipped at soil level, dried at 60 °C in a forced-air drier to constant weight, and weighed. After the four sites were clipped, the disk meter was dropped at 30 sites within the paddock in a systematic fashion. The same procedure was repeated after grazing. At the end of each grazing season, a calibration equation was developed by regressing HM on disk height using the double sampling data from all paddocks on all sampling dates. The average of the 30 disk heights was calculated and HM was estimated by entering the average disk height in the calibration equation. A single equation was used in 1993 ( $n=408$ ) and two were used in 1994 (one for GC=7 [ $n=185$ ], another for GC=21 and GC=35 [ $n=563$ ]). Prediction equations had adjusted  $r^2$  and root MSE of 0.745 and 0.987 Mg ha<sup>-1</sup> in 1993, and 0.746 and 1.154 Mg ha<sup>-1</sup> (for GC=7), and 0.591 and 1.565 Mg ha<sup>-1</sup> (for GC=35) in 1994.

Herbage accumulation (HAC) during a rest period was calculated by subtracting postgraze HM of cycle  $n-1$  from pregraze HM of cycle  $n$ . Seasonal herbage accumulation was calculated by adding the HAC values over the entire grazing season for each paddock. For paddocks where GC=7, sampling for HM was done every 21 d, although they were grazed weekly to their assigned SH. Four caged exclosures in each of these paddocks were used to calculate HAC. In these paddocks, there was no pregraze sampling. After grazing, HM was determined using double sampling, and the herbage inside the four cages (0.25 m<sup>2</sup> per cage) was clipped to soil

level, dried at 60 °C to constant weight, and weighed. Four new sites for cages were then chosen that represented the assigned postgraze SH for the paddock, and the cages were firmly anchored. Three weeks later, the same sampling procedure was repeated. Herbage accumulation over the 3-wk period was calculated as the difference between HM inside the cages and HM on the paddock 3 wk earlier.

In order to assess the effects of treatments on forage nutritive value, hand-plucked samples of herbage on offer were taken pregraze at target SH on each sampling date. Within a paddock, 20 samples were cut to make a 200-g fresh weight composite sample. These samples were dried at 60 °C in a forced-air drier to constant weight, ground in a Wiley mill to pass a 1-mm stainless steel screen, and taken to the laboratory for analyses. Nitrogen concentration was measured using a modification of the aluminum block digestion technique (Gallaher et al., 1975), and ammonia in the digestate determined by semi-automated colorimetry (Hambleton, 1977). Concentration of CP in herbage dry matter was calculated as  $N \times 6.25$ . In vitro digestible organic matter concentration was determined by the two-stage procedure of Tilley and Terry (1963) modified by Moore and Mott (1974), and neutral detergent fiber (NDF) determination followed the procedure described by Golding et al. (1985).

### Data Analysis

To determine the effects of GC and SH across years, data were analyzed using the General Linear Models procedure (PROC GLM) of the Statistical Analysis System software package (SAS Institute, Inc., 1989). In this analysis, year was treated as a

subplot in a split-plot arrangement. Interactions with year were numerous, however, so data are reported by year. Within years, data were analyzed using the Response Surface Regression procedure (PROC RSREG) of SAS (SAS Institute, Inc., 1989). This procedure tests for fitness of a second-order polynomial regression model of the form

$$y = \beta_0 + \beta_1 (GC) + \beta_2 (SH) + \beta_3 (GC)^2 + \beta_4 (SH)^2 + \beta_5 (GC \times SH) + \epsilon$$

where

$y$  = response variable

$\beta_0$  = intercept

$\beta_1$  = linear coefficient for GC

$\beta_2$  = linear coefficient for SH

$\beta_3$  = quadratic coefficient for GC

$\beta_4$  = quadratic coefficient for SH

$\beta_5$  = interaction or crossproduct coefficient for GC and SH

$\epsilon$  = experimental error term

The second-order polynomial model was also tested for lack of fit. Reduced models were fitted with the coefficient estimates that showed a significant effect in the full model ( $P \leq 0.10$ ). PROC GLM was used to test for significance ( $P \leq 0.10$ ) of the coefficient estimates in the reduced models. Terms that were not significant in the full model were included in the reduced model when higher-order terms were significant. For example, when there was a GC $\times$ SH interaction, the linear effects of both GC and SH were included in the model regardless of their level of probability. Likewise, the linear effect of a factor was included when the quadratic effect of that factor was significant.

The response surfaces generated are shown as two-dimensional projections on a plane surface (contour plots). This allows for easier reading of the expected

response at any combination of GC and SH, as well as prompt identification of zones of optimal response. For illustration purposes, two of the plots are also shown in the three-dimensional configuration. The coefficient estimates and probability levels for effects of experimental variables and their interactions are listed in Table 3.2. The  $P(|t| > t_{\alpha}) = \alpha$  values are for effects in the reduced model.

## Results and Discussion

### Herbage Accumulation

Lower mean HAC for 1993 (Figs. 3.1 and 3.2) than for 1994 (Figs. 3.3 and 3.4) was primarily related to the shorter grazing season in 1993. In both years, HAC increased with increasing SH. For any given level of SH, intermediate to long GCs tended to give lowest seasonal HAC. In 1993, all terms of the second-order polynomial were included in the reduced model except the quadratic effect of SH (root MSE=1.049 Mg ha<sup>-1</sup>). Highest HAC (13.1 Mg ha<sup>-1</sup>) was observed for the 7-24 combination of GC-SH, while lowest HAC (6.9 Mg ha<sup>-1</sup>) was measured for the 21-8 treatment. In 1993, interaction occurred because increasing postgraze SH increased HAC more rapidly when GC was 7 d than when it was longer. There was no GC×SH interaction in 1994 (Figs. 3.3 and 3.4). The 7-24 and 35-24 combinations resulted in highest HAC (root MSE=1.218 Mg ha<sup>-1</sup>). Herbage accumulation predicted by the regression model exceeded 16 Mg ha<sup>-1</sup> for both treatments but was at a maximum for the 35-24 treatment (17 Mg ha<sup>-1</sup>). Lowest HAC for a given SH was observed around GC=21. For SH=16, for example, HAC was 14.4 Mg ha<sup>-1</sup> for

Table 3.2. Coefficient estimates for the fitted regression models. Estimated response =  $b_0 + b_1(\text{GC}) + b_2(\text{SH}) + b_3(\text{GC})^2 + b_4(\text{SH})^2 + b_5(\text{GC} \times \text{SH})$ , or a reduced form of the model for responses reported in this chapter.

| Response† | Coefficient estimate |                   |                 |                  |                |                   | R <sup>2</sup> | Figure   |
|-----------|----------------------|-------------------|-----------------|------------------|----------------|-------------------|----------------|----------|
|           | b <sub>0</sub>       | b <sub>1</sub>    | b <sub>2</sub>  | b <sub>3</sub>   | b <sub>4</sub> | b <sub>5</sub>    |                |          |
| HAC 93    | 6.46                 | -0.192<br>0.1520* | 0.380<br>0.0003 | 0.0064<br>0.0326 | —              | -0.0086<br>0.0226 | 0.79           | 3.1, 3.2 |
| HAC 94    | 12.8                 | -0.360<br>0.0168  | 0.228<br>0.0001 | 0.0092<br>0.0101 | —              | —                 | 0.73           | 3.3, 3.4 |
| CP 93     | 105                  | 1.13<br>0.1080    | —               | -0.04<br>0.0285  | —              | —                 | 0.55           | 3.5      |
| CP 94     | 116                  | 1.9<br>0.0011     | —               | -0.05<br>0.0003  | —              | —                 | 0.66           | 3.6      |
| IVDOM 93  | 613                  | 1.82<br>0.0491    | 0.92<br>0.4455  | —                | —              | -0.12<br>0.0266   | 0.51           | 3.7      |
| IVDOM 94  | 532                  | 5.6<br>0.0057     | —               | -0.13<br>0.0066  | —              | —                 | 0.41           | 3.8      |

† HAC = seasonal herbage accumulation (Mg ha<sup>-1</sup>); CP = crude protein concentration (g kg<sup>-1</sup>) in hand-plucked samples averaged across sampling dates within years; IVDOM = in vitro digestible organic matter concentration (g kg<sup>-1</sup>) in hand-plucked samples averaged across sampling dates within years.

\* Significance level  $P(|t| > t_{\alpha}) = \alpha$ .

# HAC 1993

$$y = 6.46 - 0.192 (GC) + 0.38 (SH) + 0.0064 (GC)^2 - 0.0086 (GC \times SH)$$

$$R^2 = 0.79$$

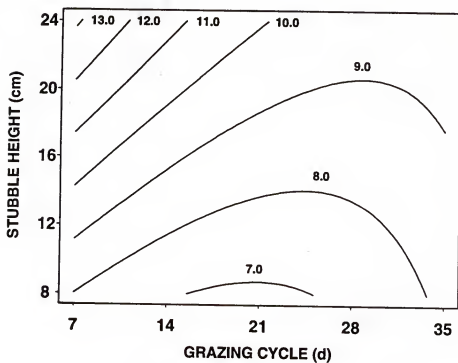


Figure 3.1. Total seasonal herbage accumulation (HAC, Mg ha<sup>-1</sup>) in 1993 as affected by grazing cycle (GC) and postgraze stubble height (SH).

## HAC 1993

$$y = 6.46 - 0.192 (GC) + 0.380 (SH) + 0.0064 (GC)^2 - 0.0086 (GC \times SH)$$

$$R^2 = 0.79$$

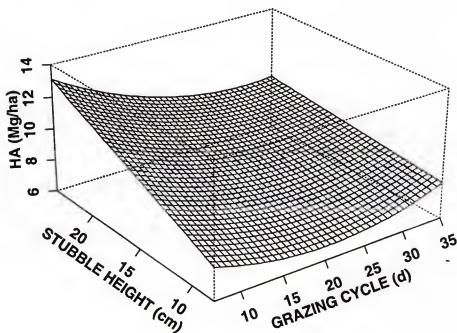


Figure 3.2. Response surface of total seasonal herbage accumulation (HAC) in 1993 as affected by grazing cycle (GC) and postgraze stubble height (SH).

## HAC 1994

$$y = 12.8 - 0.360 (GC) + 0.228 (SH) + 0.0092 (GC)^2$$

$$R^2 = 0.73$$

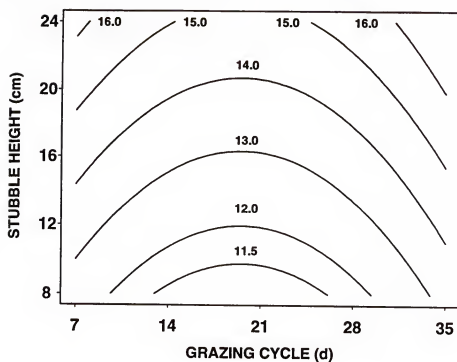


Figure 3.3. Total seasonal herbage accumulation (HAC, Mg ha<sup>-1</sup>) in 1994 as affected by grazing cycle (GC) and postgraze stubble height (SH).

## HAC 1994

$$y = 12.8 - 0.360 (GC) + 0.228 (SH) + 0.0092 (GC)^2$$

$$R^2 = 0.73$$

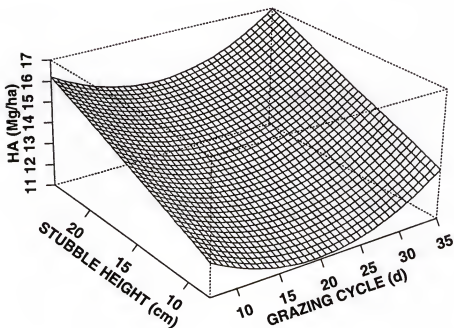


Figure 3.4. Response surface of total seasonal herbage accumulation (HAC) in 1994 as affected by grazing cycle (GC) and postgraze stubble height (SH).

GC=7, decreased to 13 Mg ha<sup>-1</sup> for GC=21, and increased to 15.2 Mg ha<sup>-1</sup> when GC=35.

Defoliation is characterized according to frequency (time interval between successive defoliations), intensity (proportion of plant material removed), and timing (season of the year or growth stage of the plant) (Humphreys, 1966; Harris, 1978). Close and frequent defoliation tends to decrease seasonal herbage yields (Harris, 1978). In the current study, lowest HAC occurred in both years when SH was 8 cm and GC was approximately 21 d. The effect of more frequent and intense defoliation has been attributed to (i) reduced light interception by photosynthetic tissue, (ii) depletion of metabolic reserves, (iii) reduced uptake of water and nutrients due to reduced root growth, and (iv) damage to meristems or depletion of seed reserves (Korte and Harris, 1987). Studying the physiology of regrowth of Coastal bermudagrass swards, Morgan and Brown (1983a, b) measured HAC of 2.0 and 0.83 kg m<sup>2</sup> for plots mowed monthly and weekly over a 96-d period, respectively. The canopy of the monthly mowed treatment developed a high LAI during a longer regrowth period, which allowed for more efficient interception of incident solar radiation. In contrast, the LAI of weekly mowed swards never reached optimum because defoliation generally occurred at LAI  $\approx$  3 and reduced it to an average of 1.4. In addition, accumulation of dead material occurred below mowing height in weekly mowed swards. When swards were mowed monthly, there was a much greater proportion of young, photosynthetically active tissue, resulting in higher canopy photosynthesis rates.

Unlike the responses observed for Coastal by Morgan and Brown (1983a, b), Florakirk HAC was consistently greater when GC was 7 than when it was 21 d for a given level of SH. For frequently and closely grazed swards, it is possible that the canopy had a higher tiller density and thus was more efficient in intercepting incoming radiation than when GC was intermediate (e.g., 21-8). Binnie and Chestnutt (1991) found evidence of an increase in tiller number when they reduced the regrowth interval of perennial ryegrass (*Lolium perenne* L. cv. Talbot) from 4 to 3 wk. In the mob-grazing trial reported here, paddocks grazed every 7 d to 8 cm visually appeared to have greater ground coverage, with plants growing more prostrate, almost turf-like, and likely with more tillers per unit area. In this situation, the continuous emergence of new tillers may have contributed substantially to interception of a high proportion of light by young, photosynthetically active tissue and thus increased carbon assimilation via photosynthesis. Hodgson (1990) explained that the decline in the rate of net carbon assimilation (difference between C taken up by photosynthesis and C evolved from respiration) as LAI decreases, is not so serious on continuously stocked or very frequently cut swards as it is on swards cut or grazed at longer intervals. This is because tiller populations are maintained at high levels on swards that are kept short, resulting in large numbers of young leaves which, because they have developed in bright light, have a high photosynthetic potential.

As the GC increased from 7 to 21 d in the current study, there may have been less stimulus to tillering. Therefore, carbon uptake may have been reduced, resulting in lower HAC when GC was 21 d. Increased HAC when GC was increased to 35 d

is likely related to optimization of LAI. In other words, tiller density was likely lower than in GC=7 treatments, but the longer regrowth interval afforded the plants time to increase LAI and grow for an extended period at optimal LAI. The proportion of leaf tissue removed by grazing may have been greatest for treatments where GC=21 because stimulation of basal tillering and the development of leaf area close to soil surface was not as great as when GC=7 and, at the same time, there was not as much time for leaf development as in treatments where GC=35.

Another possible explanation for the higher HAC observed for GC=7 than for GC=21 is that it may have been caused in part by the sampling procedure. On the GC=7 pastures, HAC was measured in caged areas of the paddock. Although the cages were rotated every 21 d to minimize variation in growth between caged areas and the pasture, it is possible that exclusion from grazing increased the measure of HAC. This procedure was necessary so as to avoid clipping a large proportion of the pasture area over the course of the season, something that would have occurred with weekly sampling. Also, errors associated with placing cages and measuring changes in HM between the pasture and the caged sites represent too high a percentage of the expected weekly growth of the pasture. Therefore, while the use of a 21-d interval for moving cages was a more practical approach to measuring HAC, it may have resulted in an overestimation of HAC when GC=7.

The increase in HAC associated with increasing SH has been addressed by Parsons (1988). He explained that in swards maintained at high LAI (i.e., taller swards), high rates of respiration result from the greater gross photosynthesis (and

hence greater 'growth' respiration) and the greater weight of live tissue to be maintained (McCree, 1970; cited by Parsons, 1988). Although the absolute amount of dry matter lost in respiration is greater in swards of high rather than low LAI, in both cases the proportion of gross photosynthesis consumed by this route (about 45%) is the same (Parsons et al., 1983b). This means that, in effect, shaded leaves respire less than illuminated leaves and as a result the gross rate of shoot production is greater in a sward maintained at a high LAI than in a sward maintained at a low LAI (Parsons, 1988).

#### Herbage Nutritive Value of Handplucked Samples

Herbage concentrations of CP and IVDOM were affected by grazing treatment in both years but in different ways. Crude protein concentrations were not affected by SH in either year ( $P > 0.20$  in 1993 [root MSE=6.07 g kg<sup>-1</sup>], and  $P > 0.57$  in 1994 [root MSE=4.34 g kg<sup>-1</sup>]) but there were linear and quadratic effects of GC in both years (Figs. 3.5 and 3.6). From short (7 d) to intermediate (21 d) levels of GC, there was a slight and perhaps not biologically important increase in CP. This was followed by a decline in CP concentration reaching a minimum at GC=35. Even so, the range in herbage CP concentration was less than 18 g kg<sup>-1</sup> in both years (96 to 113 g kg<sup>-1</sup> in 1993 and 124 to 133 g kg<sup>-1</sup> in 1994). Figures 3.5 and 3.6 show that the maximum CP concentration is predicted to occur when GC is less than 21 d, regardless of the height of the stubble left after grazing.

In 1993, there was a GC×SH interaction ( $P = 0.027$ ) affecting IVDOM concentration (Fig. 3.7; root MSE=15.46 g kg<sup>-1</sup>). There was little effect on IVDOM

# CP 1993

$$y = 105 + 1.13 (\text{GC}) - 0.04 (\text{GC})^2$$

$$R^2 = 0.55$$

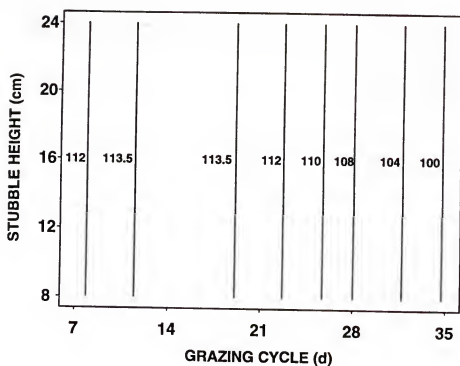


Figure 3.5. Crude protein (CP) concentration ( $\text{g kg}^{-1}$ ) in Florakirk bermudagrass herbage in 1993 as affected by grazing cycle (GC) and postgraze stubble height (SH).

## CP 1994

$$y = 116 + 1.9 (\text{GC}) - 0.05 (\text{GC})^2$$

$$R^2 = 0.66$$

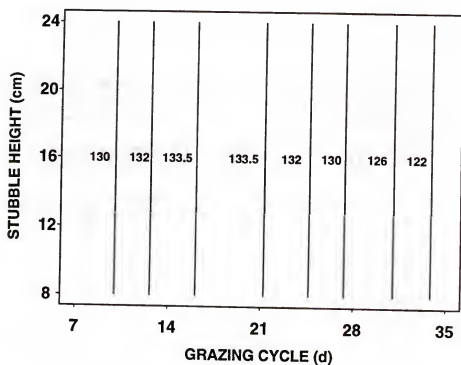


Figure 3.6. Crude protein (CP) concentration ( $\text{g kg}^{-1}$ ) in Florakirk bermudagrass herbage in 1994 as affected by grazing cycle (GC) and postgraze stubble height (SH).

# IVDOM 1993

$$y = 613 + 1.82 (GC) + 0.92 (SH) - 0.12 (GC \times SH)$$

$$R^2 = 0.51$$

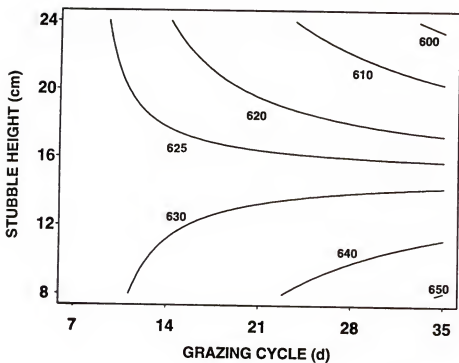


Figure 3.7. In vitro digestible organic matter (IVDOM) concentration ( $\text{g kg}^{-1}$ ) in Florakirk bermudagrass herbage in 1993 as affected by grazing cycle (GC) and postgraze stubble height (SH).

of varying SH at GC=7. Increasing SH at GC=35, however, caused a decline in IVDOM concentration from a maximum of 650 g kg<sup>-1</sup> in the 35-8 treatment, to a minimum of 598 g kg<sup>-1</sup> in the 35-24 treatment. A different response was observed in 1994, when SH did not ( $P > 0.62$ ) affect IVDOM concentration (Fig. 3.8; root MSE=15.94 g kg<sup>-1</sup>). Similar to CP concentration, there were both linear and quadratic effects of GC on IVDOM. In addition, intermediate levels of GC tended to maximize IVDOM, with declines at both ends of the GC scale. Whereas IVDOM concentration peaked at 592 g kg<sup>-1</sup> for GC=21, it was 565 and 569 g kg<sup>-1</sup> for GC=7 and GC=35, respectively. Concentration of NDF in the herbage did not respond to grazing treatments in 1993 ( $P \geq 0.178$ ; mean = 813 g kg<sup>-1</sup>) or 1994 ( $P \geq 0.199$ ; mean = 764 g kg<sup>-1</sup>).

In the current study, lower concentrations of CP and IVDOM were associated generally with longer GCs, and consequently with older regrowth. Mott and Moore (1970) stated that the nutritive value of a forage refers to its chemical composition, digestibility, and the nature of the resulting products of digestion. Several biotic and abiotic factors act in complex interactions in determining the nutritive value of forages, including species, photosynthetic pathway, morphology, climate (rainfall and temperature), ontogeny, and management, among others. Plant maturity is the major factor affecting forage quality (Moore, 1973) through its effects on plant morphology, tissue composition, and consequently, on nutritive value (Nelson and Moser, 1994). Although the maturity effects result from interplaying phenomena (Buxton and Fales, 1994), it is well accepted that the increase in the stem fraction and the decline in stem

# IVDOM 1994

$$y = 532 + 5.6 (GC) - 0.13 (GC)^2$$

$$R^2 = 0.41$$

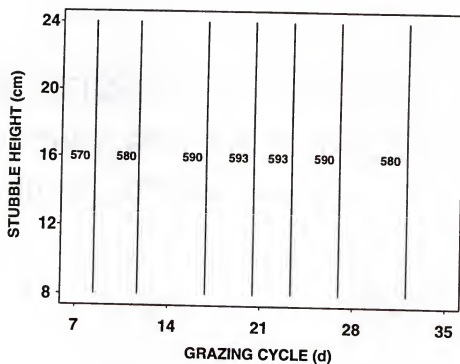


Figure 3.8. In vitro digestible organic matter (IVDOM) concentration ( $\text{g kg}^{-1}$ ) in Florakirk bermudagrass herbage in 1994 as affected by grazing cycle (GC) and postgraze stubble height (SH).

quality, are related closely to the decline in nutritive value with maturity. Although protein concentration may not always reflect overall nutritive value, a reduction in protein concentration is associated commonly with senescence and decline in nutritive value (Hoveland and Monson, 1980). This is due primarily to the breakdown and loss of nitrogenous compounds from plant tissue as it senesces (Salisbury and Ross, 1985). Mislevy et al. (1988) and Adjei et al. (1989) reported decreasing CP concentration as the interval between grazings increased for bahiagrass, limpograss, stargrass, and bermudagrass. Rates of decline were different among grasses and interacted with season of the year. Linear and quadratic effects of plant maturity (represented by GC) were observed in both years of the current study. For Florakirk pastures mob-grazed to 7.5 cm every 4 wk, Adjei et al. (1989) measured a CP concentration of  $100 \text{ g kg}^{-1}$ , whereas results of this research predict 108 and  $129 \text{ g kg}^{-1}$  for a similar grazing management in 1993 and 1994, respectively (Figs. 3.5 and 3.6). Also in the study of Adjei et al. (1989), Florakirk bermudagrass IVDOM concentration was  $560 \text{ g kg}^{-1}$  when grazed to a 7.5-cm stubble every 4 wk. The predicted response in the current study for a GC-SH combination of 28 d and 8 cm is about  $644 \text{ g kg}^{-1}$  (Fig. 3.7) in 1993 and about  $587 \text{ g kg}^{-1}$  in 1994 (Fig 3.8).

According to Minson (1971) the dry matter digestibility of tropical grasses generally decreases at a daily rate of 0.1 to 0.2 percentage units. In this study, considering the decline in IVDOM concentration from GC=21 to 35 d in the 1994 grazing season, the daily decline was  $1.6 \text{ g kg}^{-1}$ , or 0.16 percentage units. In 1993, there was a GC $\times$ SH interaction effect on IVDOM. When GC was long, taller SHs

were detrimental to digestibility perhaps because a greater proportion of the regrowth was made up by stem elongation, which reduces digestibility (Wilson and Minson, 1980). Reduced digestibility of Coastal bermudagrass stem was attributed by Akin et al. (1990) to increased presence of lignified ring tissues when plants were 6-wk old, as lignin and other free phenolic monomers are well-known inhibitors of forage digestibility (Akin, 1988; Borneman et al., 1986; Hartley and Akin, 1989; Susmel and Stefanon, 1993). This effect of SH was not observed in the short GC treatments. This is consistent with the notion that young regrowth above any SH, present at short GCs consisted mainly of leaf and possibly young stem tissue, which is often high in nutritive value (Minson, 1990).

### Summary and Conclusions

Responses of Florakirk bermudagrass to grazing management were studied in a mob-grazing trial. Treatments imposed consisted of all combinations of three levels of GC (7, 21, and 35 d) and of postgraze SH (8, 16, and 24 cm). Responses studied included seasonal HAC, and herbage CP, IVDOM, and NDF concentrations.

In this study, Florakirk was productive across a range of management practices. Herbage accumulation ranged from 6.9 to 17 Mg ha<sup>-1</sup> and was maximized when pastures were grazed to 24 cm every 7 d in 1993, and to 24 cm every 35 d in 1994. Lowest HAC occurred when pastures were grazed to 8 cm every 21 d in 1993 and in 1994. In both years, minimum HAC tended to be associated with intermediate GCs. Combinations of short GCs and tall SHs were favorable to high HAC in both

years of the study. Nutritive value of Florakirk forage varied relatively little across the range of treatments imposed in this study. Crude protein concentration ranged from 96 to 113 g kg<sup>-1</sup> in 1993 and from 121 to 134 g kg<sup>-1</sup> in 1994. Lower CP was associated with longer GCs in both years. In vitro organic matter digestibility was maximized at short SH and long GC in 1993 but at intermediate GCs in 1994. Neutral detergent fiber concentration averaged 813 g kg<sup>-1</sup> in 1993 and 764 g kg<sup>-1</sup> in 1994, and was not affected by treatments.

Because the accuracy of the HAC data for GC=7 is questionable, it is not possible to draw final conclusions from HAC responses to treatment combinations where GC=7. Higher HAC was associated with longer GCs but nutritive value declined with longer GCs. This suggests that a rotational stocking management with a 5-wk rest period will allow for greater HAC and consequently greater stocking rates and liveweight gains per unit area. If nutritive value is to be maximized so as to favor individual animal performance, shorter GCs (21 d or shorter) are better, and maximization of individual animal performance will likely require somewhat lower stocking rates. If the trend for high HAC at short GCs is real, short rest periods in rotational stocking or a continuous stocking system will allow for high stocking rates, together with good individual animal performance. This should not, however, be accepted without further investigation. In experiments like this one, preference should be given to techniques other than the use of cages to measure HAC from frequently grazed treatments. Difficulties reside in that this may require further modifications in the experimental protocol, including possibly more frequent sampling

and larger experimental units to avoid confounding between the effect of grazing and the effect of clipping too many samples from a small pasture. Measuring sward height with the disk meter before and after each grazing is a possible alternative to avoid the problem encountered in measuring HAC in this research. This approach has limitations, however, because in many cases the change in herbage mass between pregraze and postgraze may be less than the standard error of the estimate of the herbage mass prediction equation.

## CHAPTER 4 BOTANICAL COMPOSITION, CANOPY LIGHT INTERCEPTION, AND ORGANIC RESERVES OF 'FLORAKIRK' BERMUDAGRASS PASTURES UNDER DIFFERENT GRAZING SYSTEMS

### Introduction

The productivity and survival of pasture plants is determined largely by a series of interactive environmental factors of which the impact of the grazing animal is only one (Hodgkinson and Williams, 1983). According to Bouton (1992), persistence is the most important trait a forage species can possess. An appreciation of persistent forages by producers has resulted in a predominance of perennial grasses in planted pastures of the southeastern US. Persistence of grasses is, at least in part, related to their high degree of specialization and their mechanisms of tolerance to grazing. Hyder (1972) pointed out, however, that overemphasis on persistence can be unwise because this characteristic is often related inversely to herbage productivity. In addition to form characteristics 'per se' such as prostrate growth, there is the influence of plant morphology and canopy architecture on physiological processes. Canopy photosynthesis, for example, is affected strongly by pattern of light interception which, in turn, is affected by plant morphology and growth habit.

One of the ways to assess persistence is by studying regrowth vigor after successive defoliations. Gomide (1989) listed four major factors determining

regrowth: (i) shoot apex survival, (ii) residual leaf area, (iii) carbohydrate reserves, and (iv) tillering potential. The relative importance of residual leaf area and stored carbohydrate reserves in the regrowth process has been a matter of continuous controversy over the years (Harris, 1978). Interactions involving plant growth habit, management, and environment in regrowth and persistence responses, make ranking of relative importance a complex problem. Evidence exists, however, that residual leaf area and stored reserves play complementary roles in regrowth, as was observed for orchardgrass (*Dactylis glomerata* L.) by Ward and Blaser (1961), and for timothy (*Phleum pratense* L.) by Smith (1974).

Studies on regrowth physiology have shown in many cases that dependence of the plant on stored carbohydrates for recovery from defoliation does not last more than a few days (Harris, 1978; Humphreys, 1991). However, the role of stored carbohydrates, even if limited to early phases of plant recovery, does play a role in both regrowth and tissue maintenance immediately following defoliation, especially when a high proportion of photosynthetic tissue is removed by cutting or grazing. Davidson and Milthorpe (1965) reported that regrowth of orchardgrass was dependent primarily on energy provided by photosynthesis from green parts of the stubble. Studying the regrowth of green panic [*Panicum maximum* var. *trichoglume* (K. Schum.) Eyles] and buffelgrass (*Cenchrus ciliaris* L.) cv. Gayndah, Humphreys and Robinson (1966b) concluded that when moisture and nutrients were in adequate supply, regrowth was more positively dependent upon LAI than on carbohydrate status.

Volenec (1986) stated that the primary site of storage of total nonstructural carbohydrates (TNC) in forage grasses is the stem base or stubble. His conclusion was based on reports in the literature for temperate species. He observed that in tall fescue (*Festuca arundinacea* Schreb.) stubble TNC concentration declined from 834 to 517 g kg<sup>-1</sup> during the first 4 d of regrowth from an average cutting height of 6 cm. By the 10<sup>th</sup> day of regrowth, TNC concentrations were increasing and were similar to the initial concentrations by the 24<sup>th</sup> day. Adjei et al. (1988) measured TNC concentrations in different plant fractions of 'UF-5' and 'McCaleb' stargrasses (*Cynodon aethiopicus* Clayton et Harlan) and in 'Ona' stargrass (*C. nlemfuensis* Vanderyst var. *nlemfuensis*). They reported that, in all three grasses, most of the TNC was stored in the roots/crown fraction (5 cm roots + 2.5 cm above-ground stubble) as opposed to the lower stubble (2.5 to 10 cm) and upper stubble (> 10 cm) fractions. In the same study, the authors reported that increasing stocking rate caused a linear decrease in TNC concentration across grasses and plant fractions.

Forage plants that store TNC in higher portions of the stubble are poorer competitors against weeds and less persistent than those that store TNC in the crown region or in underground organs such as rhizomes. 'Transvala' digitgrass (*Digitaria eriantha* Steud.) stores most of its TNC between 2.5 and 10 cm in the stubble, and was severely weakened by heavy grazing, resulting in irreversible stand loss due to encroachment by common bermudagrass [*C. dactylon* (L.) Pers.] (Adjei et al., 1988).

'Florakirk' bermudagrass is a rhizomatous, productive cultivar that has persisted for almost 10 yr under clipping in North Florida and has survived winter

temperatures of  $-13^{\circ}\text{C}$  (Mislevy et al., 1995). The effects of grazing management on reserve status and canopy light interception of Florakirk bermudagrass pastures have not been determined. This information is needed if long-term persistence and productivity are to be optimized under grazing. Therefore, research was initiated in order to determine the effect of length of grazing cycle (GC) and postgraze stubble height (SH) on Florakirk bermudagrass (i) canopy light interception, (ii) TNC and N concentrations and pools, and (iii) changes in sward botanical composition.

### Materials and Methods

The experimental site and time frame, pasture establishment and cultural practices, experimental design and treatments, and grazing management used in this trial are the same as those reported in Chapter 3.

### Sampling

In order to estimate pasture botanical composition, samples were collected before the first and last grazing of the season in both 1993 and 1994. At the first pregraze sampling, fresh herbage clipped from each of the four  $0.25\text{-m}^2$  double sampling sites was hand-separated into Florakirk bermudagrass and weeds. The two fractions were then dried in a forced-air drier at  $60^{\circ}\text{C}$  to constant weight. The same procedure was repeated at the last pregraze sampling of the grazing season, except for paddocks where  $\text{GC}=7$  because those were not sampled pregraze. When  $\text{GC}=7$ , herbage clipped from inside the enclosure cages at the last postgraze sampling of the season was hand separated.

Light interception by the grass canopy was measured pre- and postgraze, in two consecutive mid-season grazing cycles, each year. Before and after grazing, light interception was measured at eight representative sites per paddock. For this purpose a 1-m long line quantum sensor, connected to a model LI-188B Li-Cor integrating quantum radiometer/photometer (Lambda Instruments Corp., Lincoln, NE) was used. At each of the eight sites, the probe was first held horizontally about 1.5 m above the top of the canopy, and the amount of incident sunlight recorded. The probe was then immediately inserted underneath the canopy, on the soil surface, in the same orientation as above the canopy and the amount of light reaching the probe was recorded. The amount of light intercepted was calculated as the difference between the total incoming sunlight and the amount that reached the soil surface. Percent light interception (LI) at each site was calculated as the amount of light intercepted by the canopy divided by total incident sunlight and multiplied by 100. The LI for a paddock was calculated as the average of the eight sites and two grazing cycles. Measurements were taken on clear days between 1100 and 1400 h.

Reserve status was measured in three fractions of the canopy after the first and last grazing of the season each year. On each sampling date, four 20-cm by 20-cm squares were dug out of the soil (10-cm depth) at sites that represented the assigned SH for the paddock. The sample was then divided into three fractions. The below-ground fraction is composed of roots and rhizomes down to a 10-cm depth (hereafter referred to as rhizome fraction). The fraction between soil level and 5-cm height is the base of the stubble. The top of the stubble is all plant material above the 5-cm

height. Within a paddock, the material pertaining to a fraction was combined across the four sampling sites. The below-ground fraction was washed, and all fractions were oven-dried at 105 °C for 1 h to inactivate respiratory enzymes. They were then transferred to a forced-air drier and dried at 60 °C to constant weight. All samples were ground in a Wiley mill to pass a 1-mm stainless steel screen and taken to the laboratory for determination of TNC and N.

Determination of TNC followed a modification of the procedure described by Christiansen et al. (1988). This procedure combines an enzymatic digestion phase (Smith, 1981) for conversion of starch and oligosaccharides into monosaccharides with a photometric copper reduction method for reducing sugars (Nelson, 1944). From each ground sample, 0.2 g were placed into a 25-mL Erlenmeyer flask with 5 mL of deionized water, and heated in a boiling water bath for approximately 40 min. Five mL of acetate buffer (0.2 M) were added in the flask, followed by 1 mL of an enzyme mixture for digestion. The enzyme mixture was prepared using 40.5 mL of deionized water, 2.25 mL of acetate buffer (0.2 M), 2.25 mL of invertase concentrate, and 0.06 g of amyloglucosidase. Samples were then incubated with the enzyme mixture in a shaker water bath set at 48 °C and 50 oscillations min<sup>-1</sup>, for 20 h. After incubation, the contents of each flask were poured through filter paper into a beaker. From the filtrate, an aliquot was drawn and transferred to test tubes for the colorimetric phase. The protocol called for a 20-μL aliquot, which has proven to work well for rhizome tissue. Because the concentration of TNC in the stubble fractions (0 to 5 cm, and >5 cm) was unknown, aliquot sizes differed from those

used for rhizomes (approximately 40  $\mu\text{L}$  for lower stubble tissue and as much as 70  $\mu\text{L}$  for upper stubble tissue). One mL of an alkaline reagent mixture was added to each test tube and tubes were placed in a boiling water bath for 22 min. They were then cooled and received 1 mL of arsenomolybdate reagent followed by 7 mL of deionized water, diluting the final contents to 10 mL. With each tube in duplicate, absorbance at 540 nm was read in a model 20D Milton Ray Spectrophotometer (Milton Ray Co., Rochester, NY), which had been calibrated using a series of glucose standard solutions. Because contamination with soil was variable across samples, with rhizome samples having greatest contamination, TNC concentration is presented on an organic matter (OM) basis.

All samples were analyzed for N concentration using a modification of the aluminum block digestion technique (Gallaher et al., 1975). Ammonia in the digestate was determined by semi-automated colorimetry (Hambleton, 1977). Nitrogen concentration is expressed on an OM basis.

### Data Analysis

Botanical composition (expressed as percent Florakirk bermudagrass) and light interception responses (LI pre- and postgraze) were analyzed for the effects of GC and SH across years, using the General Linear Models procedure (PROC GLM) of the Statistical Analysis System software package (SAS Institute, Inc., 1989). Year was treated as a subplot in a split-plot arrangement, and because there were interactions of treatments with year, data are reported by year. The RSREG

procedure (SAS Institute, Inc., 1989) described in Chapter 3, was used for analysis of botanical composition and light interception responses within year.

Responses related to reserve status include postgraze mass of plant fractions (rhizomes, base of stubble, top of stubble), TNC and N concentrations in each fraction, and pool of TNC and N in each fraction. Data for measures of reserve status were first analyzed using repeated measures analysis of variance (Littel et al., 1991) in space (plant fractions) and time (years). Because there were interactions of treatment and year, data are reported by year.

Within years, no differences among treatments were detected using the RSREG procedure for botanical composition and reserve status responses. Thus, orthogonal contrasts were used to test for both linear and quadratic effects of GC and SH. This analysis assigns variation included in the error term for the RSREG analysis to known sources. This results in a more powerful test of treatment effects. Polynomial contrasts were considered to be significant when  $P \leq 0.10$ . The coefficient estimates and probability levels for effects of experimental variables and their interactions on LI responses are listed in Table 4.1. The  $P(|t| > t_{\alpha}) = \alpha$  values are for effects in the reduced model.

### Results and Discussion

Botanical composition did not respond to treatments ( $P > 0.10$ ) on any of the four sampling occasions. At the end of the 1993 and 1994 grazing seasons, pastures were on average 98 and 99% Florakirk bermudagrass, respectively. Persistence of

Table 4.1. Coefficient estimates for the fitted regression model. Estimated response =  $b_0 + b_1$  (GC) +  $b_2$  (SH) +  $b_3$  (GC)<sup>2</sup> +  $b_4$  (SH)<sup>2</sup> +  $b_5$  (GC×SH), or a reduced form of the model, for responses reported in this chapter.

| Response <sup>†</sup> | Coefficient estimate |                |                              |                 |                 |                 | R <sup>2</sup> | Figure |
|-----------------------|----------------------|----------------|------------------------------|-----------------|-----------------|-----------------|----------------|--------|
|                       | $b_0$                | $b_1$          | $b_2$                        | $b_3$           | $b_4$           | $b_5$           |                |        |
| LIPOST 93             | 48                   | —              | -1.85<br>0.3927 <sup>‡</sup> | —               | 0.12<br>0.0678  | —               | 0.80           | 4.1    |
| LIPOST 94             | -23.6                | —              | 8.12<br>0.0008               | —               | -0.16<br>0.0185 | —               | 0.90           | 4.2    |
| LIPRE 93              | 22                   | 2.48<br>0.0033 | 2.09<br>0.0003               | -0.03<br>0.0684 | —               | -0.04<br>0.0432 | 0.84           | 4.3    |
| LIPRE 94              | 12.3                 | 1.74<br>0.0001 | 4.09<br>0.0002               | —               | -0.05<br>0.0576 | -0.06<br>0.0001 | 0.96           | 4.4    |

<sup>†</sup> LIPOST=Postgraze canopy light interception (%); LIPRE=Pregraze canopy light interception (%)

<sup>‡</sup> Significance level  $P(|t| > t_{\alpha}) = \alpha$ .

Florakirk was studied by Adjei et al. (1989) who found only a 3% common bermudagrass ground cover in Florakirk pastures grazed every 4 wk for 2 yr. In the same study, Tifton 78 pastures had an 89% ground cover by common bermudagrass under the same grazing treatment. Donald (1963) explained that the factors for which competition may occur among plants are water, minerals, light, O<sub>2</sub>, and CO<sub>2</sub>. Other factors affecting growth such as temperature, are not in finite supply and thus are not the subject of competition. He described a number of studies for which botanical composition of grass-legume pastures was used to assess competitiveness and the effects of defoliation upon interplant competition. In general, grasses that have high tillering potential and can respond to severe defoliation by shifting their growth habit, tend to be more competitive than those that are less tolerant to close and frequent defoliation. This has been observed in perennial ryegrass (*Lolium perenne* L.) (Kydd, 1966), tall fescue (*Festuca arundinacea* Schreb.) (Matches, 1992), and Coastal bermudagrass (Roth et al., 1985; cited by Matches, 1992). Donald (1963) explained that this is related to the ability of grasses to retain photosynthetic surface after defoliation, and compete efficiently for light.

In the current study, LI was greatly affected by treatment and cannot account for the lack of a botanical composition response. Predicted values of postgraze LI ranged from 41 to 78% in 1993 (root MSE=8.33%) and from 31 to 81% in 1994 (root MSE=7.64%). In both years, postgraze LI was influenced only by SH. The response was curvilinear (Figs. 4.1 and 4.2) but different between years. Whereas in 1993, LI increased at an increasing rate as SH went from 8 to 24 cm, the increase

## Postgraze LI 1993

$$y = 48 - 1.85 (\text{SH}) + 0.12 (\text{SH})^2$$

$$R^2 = 0.80$$

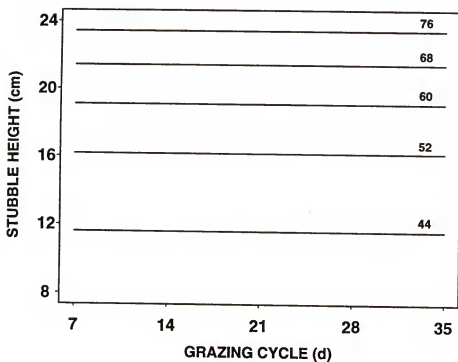


Figure 4.1. Postgraze canopy light interception (LI, %) in 1993 as affected by length of grazing cycle (GC) and postgraze stubble height (SH).

## Postgraze LI 1994

$$y = -23.6 + 8.12 (\text{SH}) - 0.16 (\text{SH})^2$$

$$R^2 = 0.90$$

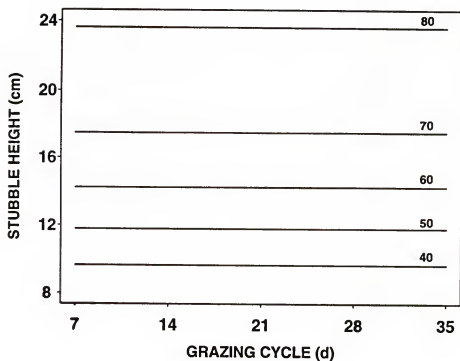


Figure 4.2. Postgraze canopy light interception (LI, %) in 1994 as affected by length of grazing cycle (GC) and postgraze stubble height (SH).

was at a decreasing rate in 1994 for the same range of SH values. This can also be seen in the prediction equation for LI in both years. The coefficient for the quadratic effect of SH was positive in 1993 but negative in 1994 (Table 4.1). The fact that GC did not affect postgraze LI suggests that any morphological responses to GC that could affect LI, either happened above the 24-cm height and thus were never present postgraze, or could not be detected by the quantum sensor if, for example, they took place very close to the soil surface. At the end of both grazing seasons, the grass on paddocks that had been closely and frequently grazed (GC=7 and SH=8) was growing close to the soil surface, almost turf-like, with short leaves and excellent ground coverage. It is likely that this shift in growth habit happened gradually following the start of the experiment, and that by mid-season when LI measurements were taken it had already occurred to some extent. Thus, the insertion of the light probe completely underneath the canopy was not possible and LI was likely underestimated under these circumstances. Similar to the observations reported in the current study, Ortega-S. et al. (1992b) found postgraze LI of 'Florigaze' rhizoma peanut (*Arachis glabrata* Benth.) to be affected by residual dry matter (linear and quadratic effects) left on pasture after grazing.

Predicted pregraze LI ranged from 52 to 91% in 1993 (root MSE=5.75%) and from 51 to 94% in 1994 (root MSE=3.06%) and was affected by GC (linear), SH (linear and quadratic), and their interaction in both years (Figs. 4.3 and 4.4). Lowest pregraze LI was observed in paddocks that were frequently and closely grazed (under 60% LI in both years). The 1993 response contour shows that 90% LI would occur

## Pregraze LI 1993

$$y = 22 + 2.48 (GC) + 2.09 (SH) - 0.03 (GC)^2 - 0.04 (GC \times SH)$$

$$R^2 = 0.84$$

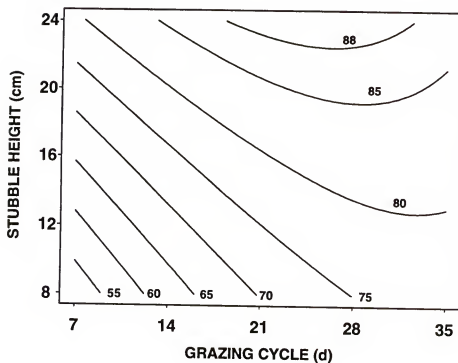


Figure 4.3. Pregraze canopy light interception (LI, %) in 1993 as affected by length of grazing cycle (GC) and postgraze stubble height (SH).

## Pregraze LI 1994

$$y = 12.3 + 1.74 (GC) + 4.09 (SH) - 0.05 (SH)^2 - 0.06 (GC \times SH)$$

$$R^2 = 0.96$$

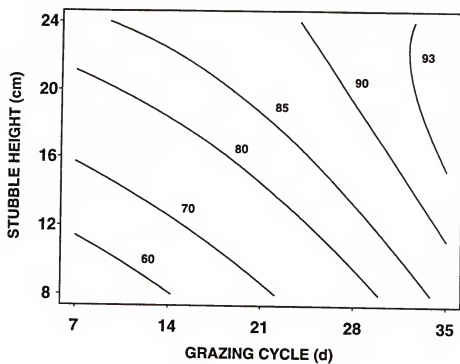


Figure 4.4. Pregraze canopy light interception (LI, %) in 1994 as affected by length of grazing cycle (GC) and postgraze stubble height (SH).

at GC of approximately 28 d for pastures grazed to 24 cm (Fig. 4.3). In 1994, long GCs allowed for LI > 90% even at intermediate (16 cm) SHs. During the 1994 grazing season, pastures grazed to 8 cm achieved 85% LI only after 35 d of regrowth. Pastures grazed to 24 cm required approximately 10 d to reach 85% LI.

Mass of rhizomes declined linearly with increasing SH in both years (Table 4.2). Ortega-S. et al. (1992b) observed a decline in rhizome mass of 'Florigraze' rhizoma peanut as pastures were grazed more frequently and to a lower postgraze residual dry matter. In their study, residual dry matter had a greater effect on rhizome mass than length of grazing cycle. In addition, the effect of lower rhizome mass due to decreased residual dry matter was greater for shorter grazing cycles. A decline in root mass of caucasian bluestem [*Bothriochloa caucasica* (Trin.) C.E. Hubb.] due to close and frequent grazing was observed by Svejcar and Christiansen (1987) at the end of both the first and second grazing seasons. In the current study, the association between greater rhizome weights and shorter SHs suggests that Florakirk bermudagrass responds to close grazing through a tolerance mechanism. Vallentine (1990) proposed that by modifying their growth habit under close and continuous defoliation, plants may be able to adapt to the grazing treatment imposed and continue to take up more carbon than required for growth and maintenance. Leaf area from the shorter SH treatments developed at high light intensities and was probably more photosynthetically efficient than the taller SHs, where senescence and decomposition may account for significant losses of carbon via respiration, resulting in lower net accumulation (Hodgson, 1990; Chapter 3). Carbon from underground

Table 4.2. Weight of rhizome fraction at the end of the 1993 and 1994 grazing seasons, as affected by postgraze stubble height.

| Year | Postgraze stubble (cm)            |      |      | OPC <sup>†</sup> | CV      |
|------|-----------------------------------|------|------|------------------|---------|
|      | 8                                 | 16   | 24   |                  |         |
|      | ----- kg OM m <sup>-2</sup> ----- |      |      |                  | -- % -- |
| 1993 | 0.91                              | 0.73 | 0.54 | L*               | 30.4    |
| 1994 | 0.78                              | 0.67 | 0.53 | L*               | 19.9    |

<sup>†</sup> Orthogonal polynomial coefficients for postgraze stubble height within year. Data are means across grazing cycles. L=linear. Significance: \* for  $0.01 < P \leq 0.05$ .

parts such as rhizomes, may be exported for tissue maintenance if those shaded plant parts become too strong of a sink for photosynthate and this could, at least partially, explain the lower rhizome weights at higher SHs.

The concentration of TNC in rhizomes was affected only by SH in 1993 and only by GC in 1994 (Tables 4.3 and 4.4). In 1993, TNC concentration increased in a curvilinear fashion with increasing SH up to 16 cm, but 1994 rhizome TNC concentrations were less than half those in 1993 (Table 4.3). In 1994, an increase in GC from 7 to 21 d resulted in a decrease in rhizome TNC concentration, but TNC concentration increased as GC increased from 21 to 35 d. Adjei et al. (1988) observed that stem bases (crown) plus roots were major carbohydrate storage locations in three stargrass cultivars. They also reported that increasing the stocking rate from 7.5 to 15 steers ha<sup>-1</sup> caused a linear decline in the TNC concentration from 53 to 46 g kg<sup>-1</sup> in average. Reis et al. (1985) observed a decline followed by an

Table 4.3. Concentration of TNC in rhizomes at the end of the 1993 and 1994 grazing seasons, as affected by postgraze stubble height.

| Year | Postgraze stubble (cm)            |     |    | OPC <sup>†</sup> | CV      |
|------|-----------------------------------|-----|----|------------------|---------|
|      | 8                                 | 16  | 24 |                  |         |
|      | ----- g kg <sup>-1</sup> OM ----- |     |    |                  | -- % -- |
| 1993 | 91                                | 107 | 99 | L, Q**           | 7.0     |
| 1994 | 44                                | 45  | 41 | n.s.             | 28.4    |

<sup>†</sup> Orthogonal polynomial coefficients for postgraze stubble height within year. Data are means across grazing cycles. L=linear; Q=quadratic.

Significance: \*\* for  $P \leq 0.01$ ; no asterisk following letter for  $0.05 < P \leq 0.10$ .

Table 4.4. Concentration of TNC in rhizomes at the end of the 1993 and 1994 grazing seasons, as affected by length of grazing cycle.

| Year | Grazing cycle (d)                 |    |    | OPC <sup>†</sup> | CV      |
|------|-----------------------------------|----|----|------------------|---------|
|      | 7                                 | 21 | 35 |                  |         |
|      | ----- g kg <sup>-1</sup> OM ----- |    |    |                  | -- % -- |
| 1993 | 109                               | 96 | 98 | n.s.             | 7.0     |
| 1994 | 41                                | 33 | 57 | L, Q*            | 28.4    |

<sup>†</sup> Orthogonal polynomial coefficients for length of grazing cycle within year. Data are means across postgraze stubble heights. L=linear; Q=quadratic.

Significance: \* for  $0.01 < P \leq 0.05$ , no asterisk following letter for  $0.05 < P \leq 0.10$ .

increase in TNC concentration in roots of *Brachiaria decumbens* Stapf. during the days after cutting, but they were not able to detect a clear, long-term pattern in stubble TNC response to defoliation. A reduction in root/rhizome TNC concentration following defoliation has been attributed to continuing respiration of those underground organs associated with a sudden cessation in carbon uptake due to loss of photosynthesizing leaf area (Sheard, 1973). In addition, stored TNC may contribute energy to regrowth, being more or less important depending on plant species and defoliation severity. Booysen and Nelson (1975) reported that under severe defoliation regrowth of tall fescue was more dependent on reserves than on residual leaf area although both factors played complementary roles under more lenient defoliation. Ball et al. (1991) explained that warm-season grasses with erect growth habit such as johnsongrass (*Sorghum halepense* L.), switchgrass (*Panicum virgatum* L.), and big bluestem (*Andropogon girardii* Vitman), store a large proportion of their carbohydrate reserves in the lower portions of the stubble. For this reason, those grasses should not be grazed closely and frequently, or their persistence will be compromised as regrowth vigor tends to decline due to depletion of reserves. The authors also argue that low-growing, warm-season species such as bahiagrass and bermudagrass are able to withstand close and continuous defoliation because they maintain large quantities of leaf area close to the soil surface. In addition, stolons and rhizomes, never removed by cutting or grazing, are usually the major carbohydrate storage organs in these species. In the current study, the lack of

consistent or large-scale effects of grazing management on Florakirk rhizome TNC concentration, support the concepts suggested by Ball et al. (1991).

The base of the stubble can be an important site of TNC storage even in low-growing grasses such as tall fescue (Volenc, 1986). In the 1993 season of the current study, there was a quadratic effect ( $P < 0.01$ ) of SH on TNC in the base of the stubble. Concentration of TNC peaked at  $79 \text{ g kg}^{-1}$  when SH was 16 cm and was approximately  $65 \text{ g kg}^{-1}$  for the shortest and tallest SHs. No effect of GC was observed in 1993. In 1994, there was a GC $\times$ SH interaction ( $P = 0.0629$ ) affecting TNC in the base of the stubble (Table 4.5). At the two lower levels of SH, TNC concentration increased linearly with increasing GC, but when SH was 24 cm there was no effect of GC. Within GCs, there was a trend (not significant at GC=7) for declining in TNC concentration as SH increased.

The size of TNC pool (the product of TNC concentration and the mass of the portion of the plant where it was measured) has sometimes been associated with persistence of forage plants under defoliation. Smaller TNC pools have been associated with more severe defoliation management (Chaparro, 1991; Spitaleri et al., 1994). In the current study, the size of TNC pool in the two lower fractions (base of the stubble plus rhizomes) decreased linearly as SH increased, in both years (Table 4.6). This response is due in large part to the effect of SH on rhizome mass (Table 4.2). There was no response of TNC pool to GC in 1993, but there was a linear increase with increasing GC in 1994 (Table 4.7). Chaparro (1991) and Spitaleri et al. (1994) found that TNC pool in rhizomes of *Pennisetum spp.* was reduced strongly by

Table 4.5. Interaction effects of length of grazing cycle and postgraze stubble height on TNC concentration in the base of the stubble at the end of the 1994 grazing season.

| Postgraze stubble (cm) | Grazing cycle (d)                 |      |      | OPC <sup>†</sup> | CV      |
|------------------------|-----------------------------------|------|------|------------------|---------|
|                        | 7                                 | 21   | 35   |                  |         |
|                        | ----- g kg <sup>-1</sup> OM ----- |      |      |                  | -- % -- |
| 8                      | 23                                | 34   | 44   | L                | 19.7    |
| 16                     | 20                                | 23   | 38   | L*               | 11.6    |
| 24                     | 15                                | 15   | 13   | n.s.             | 7.8     |
| OPC <sup>†</sup>       | n.s.                              | L*   | L*   |                  |         |
| CV (%)                 | 24.7                              | 17.7 | 14.7 |                  |         |

<sup>†</sup> Orthogonal polynomial coefficients for length of grazing cycle within a postgraze stubble height. L=linear.

<sup>†</sup> Orthogonal polynomial coefficients for postgraze stubble height within a length of grazing cycle. L=linear.

Significance: \* for  $0.01 < P \leq 0.05$ , no asterisk following letter for  $0.05 < P \leq 0.10$ .

Table 4.6. Pool of TNC in the base of the stubble plus rhizomes at the end of the 1993 and 1994 grazing seasons, as affected by postgraze stubble height.

| Year | Postgraze stubble (cm)        |    |    | OPC <sup>†</sup> | CV      |
|------|-------------------------------|----|----|------------------|---------|
|      | 8                             | 16 | 24 |                  |         |
|      | ----- g m <sup>-2</sup> ----- |    |    |                  | -- % -- |
| 1993 | 96                            | 94 | 68 | L                | 27.7    |
| 1994 | 44                            | 38 | 27 | L                | 40.6    |

<sup>†</sup> Orthogonal polynomial coefficients for postgraze stubble height within year. Data are means across grazing cycles. L=linear.

Significance: no asterisk following letter indicates  $0.05 < P \leq 0.10$ .

Table 4.7. Pool of TNC in the base of the stubble plus rhizomes at the end of the 1993 and 1994 grazing seasons, as affected by length of grazing cycle.

| Year | Grazing cycle (d)             |    |    | OPC <sup>†</sup> | CV      |
|------|-------------------------------|----|----|------------------|---------|
|      | 7                             | 21 | 35 |                  |         |
|      | ----- g m <sup>-2</sup> ----- |    |    |                  | -- % -- |
| 1993 | 86                            | 87 | 85 | n.s.             | 27.7    |
| 1994 | 32                            | 29 | 49 | L                | 40.6    |

<sup>†</sup> Orthogonal polynomial coefficients for length of grazing cycle within year. Data are means across postgraze stubble heights. L=linear.

Significance: no asterisk following letter indicates  $0.05 < P \leq 0.10$ .

severe defoliation. They found a close relationship between TNC pool and persistence.

More than 50% of the TNC in Florakirk bermudagrass was found in rhizomes, in agreement with Ball et al. (1991). There was a GC×SH interaction ( $P < 0.05$ ) effect on the proportion of total TNC pool in the rhizome fraction in 1993 (Table 4.8). Within a level of GC, the proportion of TNC pool in rhizomes declined linearly as SH increased. However, the effect of GC depended on the level of SH and it was absent for SH=16. At SH=8, the effect of GC was quadratic, peaking at GC=21 where 82% of the TNC pool was found in rhizomes. When SH=24, increasing GC increased the proportion of TNC pool in rhizomes linearly. This response was not affected by treatments in 1994.

When the TNC pool in the base of the stubble was added to that in rhizomes, these two fractions contained as much as 93% of the total TNC pool (Table 4.9).

Table 4.8. Interaction effects of length of grazing cycle and postgraze stubble height on the proportion of total TNC pool located in the rhizome fraction at the end of the 1993 grazing season.

| Postgraze<br>stubble<br>(cm) | Grazing cycle (d) |     |     | OPC <sup>†</sup> | CV      |
|------------------------------|-------------------|-----|-----|------------------|---------|
|                              | 7                 | 21  | 35  |                  |         |
|                              | ----- % -----     |     |     |                  | -- % -- |
| 8                            | 70                | 82  | 76  | Q                | 4.2     |
| 16                           | 67                | 65  | 68  | n.s.             | 4.6     |
| 24                           | 53                | 60  | 63  | L                | 5.8     |
| OPC <sup>‡</sup>             | L*                | L*  | L** |                  |         |
| CV (%)                       | 3.9               | 5.7 | 1.9 |                  |         |

<sup>†</sup> Orthogonal polynomial coefficients for length of grazing cycle within a postgraze stubble height. L=linear; Q=quadratic.

<sup>‡</sup> Orthogonal polynomial coefficients for postgraze stubble height within a length of grazing cycle. L=linear.

Significance: \*\* for  $P \leq 0.01$ , \* for  $0.01 < P \leq 0.05$ , no asterisk following letter for  $0.05 < P \leq 0.10$ .

Table 4.9. Proportion of total TNC pool located in the two lower fractions (base of the stubble plus rhizomes) at the end of the 1993 and 1994 grazing seasons, as affected by postgraze stubble height.

| Year | Postgraze stubble (cm) |    |    | OPC <sup>†</sup> | CV      |
|------|------------------------|----|----|------------------|---------|
|      | 8                      | 16 | 24 |                  |         |
|      | ----- % -----          |    |    |                  | -- % -- |
| 1993 | 89                     | 81 | 75 | L**              | 2.1     |
| 1994 | 93                     | 81 | 63 | L**              | 8.8     |

<sup>†</sup> Orthogonal polynomial coefficients for postgraze stubble height within year. Data are means across grazing cycles. L=linear.

Significance: \*\* indicates  $P \leq 0.01$ .

The proportion of total TNC pool in this combined fraction was affected by both GC and SH in each year. Increasing SH caused a linear reduction in the proportion of pool found in rhizomes plus base of stubble (Table 4.9). This response was due in part to the greater amount of herbage and TNC above 5 cm when SH was 16 or 24 cm than when SH was 8 cm. Increasing GC caused a linear increase in the response in both years (Table 4.10) although the magnitude of this increase was never greater than 10 percentage units. These results suggest that, although the base of bermudagrass stubble may store significant amounts of TNC (Adjei et al., 1988), the most important storage organs are below the soil surface.

One striking aspect of the TNC data for Florakirk bermudagrass in this study, is the marked decline in concentration and pool in rhizomes and in the combined rhizome + base of stubble fractions in 1994 compared with 1993 (Tables 4.3, 4.4, 4.6, and 4.7). Decline in winter survival and persistence of *Pennisetum spp.* has been associated with reduced rhizome TNC concentration and pool due to more intensive defoliation during the growing season (Spitaleri et al., 1994). Ortega-S. et al. (1992b) reported lowest rhizome TNC concentration and lowest rhizome mass for rhizoma peanut pastures grazed most frequently (every 7 d) to low residual dry matter (500 kg ha<sup>-1</sup>). For the same defoliation treatment, pastures had the lowest rhizoma peanut percentage (Ortega-S. et al., 1992a). Rhizoma peanut percentage in frequently and closely grazed pastures decreased from 90 to 27% in the first grazing season, and from 27 to 9% in the second grazing season. In the current study, however, the decline in TNC concentration and pool observed at the end of the second grazing

Table 4.10. Proportion of total TNC pool located in the two lower fractions (base of the stubble plus rhizomes) at the end of the 1993 and 1994 grazing seasons, as affected by length of grazing cycle.

| Year | Grazing cycle (d) |    |       | OPC <sup>†</sup> | CV      |
|------|-------------------|----|-------|------------------|---------|
|      | 7                 | 21 | 35    |                  |         |
|      | -----             | %  | ----- |                  | -- % -- |
| 1993 | 80                | 82 | 82    | L                | 2.1     |
| 1994 | 78                | 75 | 85    | L                | 8.8     |

<sup>†</sup> Orthogonal polynomial coefficients for postgraze stubble height within year, averaged across grazing cycles. L=linear.

Significance: no asterisk following letter indicates  $0.05 < P \leq 0.10$ .

season were not accompanied by other indications of loss of vigor. While some serious weed encroachment and stand loss were noticed in a companion study where continuously stocked Florakirk pastures were maintained at a 20-cm height (Chapter 5), results from the current study do not indicate that close and frequent grazing are detrimental to persistence. At the end of the second grazing season, pastures where GC=7 and SH=8 (and all other treatments where SH=8) were 100% Florakirk. Therefore, rather than a harbinger of a possible stand collapse, the reduced TNC concentrations and pools seen at the end of the second year of grazing, may be the result of an adaptation phenomenon whereby Florakirk bermudagrass shifts its growth habit becoming more prostrate under close and frequent grazing. Regrowth would then rely more on residual leaf area left after grazing, with organic reserves now fluctuating around a new, lower base value than before the form adaptations took place.

Pool of N in the two lower plant fractions was not affected by treatments in either year, averaging  $6 \text{ g m}^{-2}$  at season end in 1993 and  $7 \text{ g m}^{-2}$  in 1994. Although an association between stored carbohydrates and N compounds is accepted in the dynamics of organic reserves of forage plants (Smith, 1973; Perry and Moser, 1974; Vickery, 1981), nitrogenous compounds do not seem to be stored and utilized in the same way as the carbon compounds (White, 1973). This may be the reason why TNC responses to grazing treatments were more evident than N responses.

### Summary and Conclusions

Persistence-related responses of Florakirk bermudagrass were measured in a trial where pastures were mob-grazed every 7, 21, or 35 d to 8, 16, or 24 cm. Data on botanical composition, pre- and postgraze canopy light interception, and plant reserve status were collected.

Botanical composition was not affected by grazing treatments. The percentage of Florakirk in pasture herbage mass at the end of the second grazing season was never below 96 for any GC-SH combination.

Predicted postgraze LI was as low as 22% for SH=8, but was never less than 78% when SH=24. Length of GC did not affect postgraze LI in either year. Pregraze LI was as high as 91% in 1993 and 94% in 1994. Lowest pregraze LI was associated with short GCs and SHs, as both treatment factors affected this response. Less than complete light interception, especially at the shorter GCs and SHs, did not seem to have any detrimental effects on botanical composition. Florakirk was an

aggressive colonizer and responded quickly to close, frequent grazing by assuming a prostrate growth habit and tillering profusely. The adoption of a prostrate growth habit under heavier grazing allowed significant leaf area to remain after grazing and may have reduced the need for storage of reserves and their mobilization for regrowth.

Rhizome mass declined linearly with increasing SH in both years, from 0.91 to 0.54 g OM m<sup>-2</sup> in 1993 and from 0.78 to 0.53 g OM m<sup>-2</sup> in 1994. Pool of TNC in rhizomes plus stem bases declined with increasing SH in both years (96 to 68 g m<sup>-2</sup> in 1993, and 44 to 27 g m<sup>-2</sup> in 1994) primarily resulting from similar changes in rhizome mass. For most treatments, TNC stored in Florakirk rhizomes accounted for more than 60% of the total TNC pool (never less than 53%). Lower mean rhizome TNC concentrations and pools in 1994 compared with 1993 did not appear to be associated with stand loss or decreased plant survival, although their long-term significance is not clear.

Under the conditions of this experiment Florakirk bermudagrass appears to be a persistent forage in North Florida. It responds to heavy grazing by altering its growth habit, maintaining ungrazed leaf area close to the soil surface, and apparently by reducing its reliance on carbohydrate reserves for regrowth.

## CHAPTER 5 ANIMAL AND FORAGE RESPONSES ON CONTINUOUSLY STOCKED 'FLORAKIRK' AND 'TIFTON 85' BERMUDAGRASS PASTURES

### Introduction

Cow-calf production is the major beef cattle enterprise in the southeastern US (Wilson and Watson, 1985). At least 80% of the weaned calves are sold to producers in the Great Plains and Midwest. Not only in Florida but across the southeastern US, the efficiency of these livestock systems is low and could benefit from controlling the breeding season, improved animal health care, and the successful introduction of better forages (Hoveland, 1986).

In the Lower South cows are grazed mainly on pastures of bahiagrass (*Paspalum notatum* Flügge), hybrid bermudagrasses [*Cynodon dactylon* (L.) Pers.], and dallisgrass (*Paspalum dilatatum* Poir.) (Hoveland, 1986). In addition to those species, digitgrasses (*Digitaria eriantha* Steud.), stargrasses (*Cynodon nlemfuënsis* Vanderyst var. *nlemfuënsis* and *C. aethiopicus* Clayton et Harlan), and limpograsses (*Hemarthria altissima* Stapf. et C.E. Hubb.) are also used to variable extents in Florida.

Ball et al. (1991) argued that the primary objectives in efficient cow-calf production should be to (i) maintain the cow as cheaply as possible, (ii) obtain good reproduction, and (iii) attain high calf weaning weights. Those authors also stated

that to achieve such objectives, it is necessary to produce forage in pastures and hay fields at a low cost and of sufficient quality to meet the needs of the animals with minimal supplement feeding.

According to Hoveland (1986), opportunities exist for increasing the efficiency of the beef cattle industry in the southeastern US. These include stockering beef steers on high quality pasture such as endophyte-free tall fescue (*Festuca arundinacea* Schreb.), alfalfa (*Medicago sativa* L.), small grains, clover (*Trifolium spp.*), and possibly improved bermudagrasses. Due to poor adaptation, however, high quality temperate grasses and legumes continue to represent a more viable option for the Upper South and Piedmont region than for the Lower South and Coastal Plain. In the latter two regions, warm-season grasses will continue to be the backbone of the beef cattle industry. Improved warm-season grasses that are productive and persistent under the existing environmental constraints, and that can provide the highest possible quality grazed forage, have the potential to increase the efficiency and profitability of beef cow-calf systems in the South, particularly in Florida.

Two newly released bermudagrass hybrids are 'Tifton 85' (Burton et al., 1993) and 'Florakirk' (Mislevy et al., 1995). Tifton 85 and 'Tifton 78' were compared under grazing in South Georgia (Hill et al., 1993). Steer average daily gain (ADG) was the same for the two grasses (0.66 kg) but Tifton 85 had a higher carrying capacity (CC; 1823 vs. 1320 steer days ha<sup>-1</sup>) and gave a greater gain per hectare (1156 vs. 789 kg) than Tifton 78. Hill et al. (1993) also measured herbage accumulation (HAC) in clipped plots. Herbage accumulation was greater for Tifton

85 ( $14.7 \text{ Mg ha}^{-1}$ ) than for Tifton 78 ( $11.3 \text{ Mg ha}^{-1}$ ) and this likely explains the greater CC and gain  $\text{ha}^{-1}$  of Tifton 85 in the grazing experiment. Florakirk bermudagrass was compared to 'Florico' and 'Florona' stargrasses under grazing in South Central Florida (Larbi et al., 1990). On pastures rotationally stocked with yearling beef steers, ADG was lower for Florakirk ( $0.38 \text{ kg}$ ) than for Florico ( $0.5 \text{ kg}$ ) and Florona ( $0.42 \text{ kg}$ ). Carrying capacity of Florakirk pastures ( $1330 \text{ kg liveweight ha}^{-1} \text{ d}^{-1}$ ) was the lowest of the three grasses and so was HAC ( $15.8 \text{ Mg ha}^{-1}$ ). Carrying capacity and HAC of the stargrasses averaged  $1510 \text{ kg LW ha}^{-1} \text{ d}^{-1}$  and  $17.5 \text{ Mg ha}^{-1}$ , respectively.

There are no reports in the literature of comparisons between Tifton 85 and Florakirk bermudagrasses under grazing. Research was initiated in order to quantify and compare animal and pasture responses on grazed pastures of Florakirk and Tifton 85 bermudagrasses. Specific objectives were to compare (i) pasture productivity, nutritive value, and carrying capacity, and (ii) yearling beef heifer average daily gain and gain per hectare on Florakirk and Tifton 85 pastures grazed continuously at a variable stocking rate.

### Materials and Methods

#### Pasture Establishment

A grazing trial was conducted at the Forage Evaluation Field Laboratory, located within the University of Florida Beef Research Unit, 18 km northeast of Gainesville, FL. A complete physical description of the experimental site is provided

in Chapter 3. Data were collected during the 1994 grazing season and monthly rainfall totals for that year are shown in Table 3.1.

Two 1-ha Florakirk bermudagrass pastures were established from tops on 13 July and 23 Oct. 1992. They were not grazed in 1993 but one hay harvest was made in late summer. Fertilization and weed control in 1993 followed the same schedule as for the area used in the mob-grazing study reported in Chapter 3. Two 1-ha Tifton 85 bermudagrass pastures were established from sprigs on 22 July 1993. They received a pre-planting fertilization of 34, 15, and 28 kg ha<sup>-1</sup> of N, P, and K, respectively on 19 July, and were sprayed with 2,4-D [(2,4-dichlorophenoxy) acetic acid] at 1 kg a.i. ha<sup>-1</sup> on 23 July and 3 September. Nitrogen (56 kg ha<sup>-1</sup>) was applied as NH<sub>4</sub>NO<sub>3</sub> on 16 August and 14 September. To ensure plant survival during establishment, pastures received 12 mm of irrigation at planting and again on 5 September.

Soil samples were collected from all pastures in December 1993. Across pastures, mean soil pH was 5.2 and Mehlich I extractable P, K, Mg, and Ca concentrations were 13, 7, 57, and 462 mg kg<sup>-1</sup>, respectively. Before grazing started in 1994, all pastures were mowed to a 15-cm stubble to remove material killed by frost during the previous winter. Pastures were sprayed with 2,4-D (1 kg a.i. ha<sup>-1</sup>) on 31 March, and received 45, 20, and 74 kg ha<sup>-1</sup> of N, P, and K, respectively, on 6 April. Each 1-ha pasture was divided in half by electric fence. In 1994, all pastures received applications of 56 kg N ha<sup>-1</sup> as NH<sub>4</sub>NO<sub>3</sub> on 10 June, 13 July, and 23 August.

### Experimental Design and Grazing Management

Pasture and animal responses were measured using 0.5-ha pastures as experimental units in a completely randomized design with three replications of each treatment (grass). Pastures were stocked continuously with crossbred yearling beef heifers using a variable ("put-and-take") stocking rate (Mott and Lucas, 1952; Mott, 1961). Two tester animals were assigned to remain on each pasture over the entire grazing season. Grazer animals (or "put-and-takes") were added to or removed from a pasture depending on forage availability. An attempt was made to keep herbage mass (HM) constant across experimental units over the season, by maintaining a sward height as close to 20 cm as possible. Within an experimental unit, one tester animal was 50% Brahman (*Bos indicus*) and 50% Angus (*Bos taurus*), and the other was 75% Brahman and 25% Angus. Stocking rates were evaluated weekly, but most adjustments occurred in conjunction with weigh days (every 28 d).

All pastures contained a portable shade structure, waterer, and mineral feeder. A salt-based trace mineral mixture was supplied free choice throughout the grazing season. Average liveweight (LW) of testers was 305 kg at the start of the experiment. Grazing commenced on 12 May in all pastures and ended on 13 October in Tifton 85 pastures (160 d of grazing). Grazing ended on 15 September, 29 September, and 13 October for the three Florakirk pastures (avg. of 141 d of grazing). Grazing terminated in a pasture when it could no longer support the two tester animals, as determined by weekly evaluation of sward height.

### Pasture and Animal Data Collection

Pastures were sampled for HM prior to initiation of grazing on 12 May, and every 2 wk thereafter. A double-sampling technique was used that included indirect measures done with a disk meter (Santillan et al., 1979). In each pasture, 30 disk heights were taken systematically and the mean disk height calculated. The disk meter was calibrated every 4 wk (i.e., every other sampling). On those occasions, three sites (0.25 m<sup>2</sup>) representing the range of HM were first measured with the disk meter and then clipped to a 5-cm height. These samples were dried at 60 °C in a forced-air drier to constant weight. The relationship between HM and disk height was determined using regression analysis and a single regression equation was used for the two grasses [HM (Mg ha<sup>-1</sup>) = - 0.540 + 0.241 × disk height (cm); n=100;  $r^2 = 0.644$ ; root MSE = 1.138 Mg ha<sup>-1</sup>]. The mean disk height of each pasture on each sampling date was entered in the equation and HM calculated.

Herbage accumulation was determined using three caged exclosures per pasture. On a given sampling date, cages were placed at three sites that represented the mean disk height of the pasture. Two weeks later, the cages were removed, the disk height of the grass was measured, and three new representative sites (mean disk height) chosen for placement of cages. Disk heights were entered in the regression equation and in each cage, HAC was calculated as the increase in HM over the 2-wk period. For each pasture, HAC was calculated as the mean HAC of the three caged sites.

Samples that represented the grazed portion of the grass canopy were collected for laboratory analyses on each sampling date. Within a given pasture, hand-plucked samples were collected from the top 5 cm of the canopy at 20 representative sites. The composite sample (approx. 200 g fresh weight) was dried at 60 °C in a forced-air drier to constant weight, ground in a Wiley mill to pass a 1-mm stainless steel screen, and taken to the laboratory for analyses. Nitrogen concentration was measured using a modification of the aluminum block digestion technique (Gallaher et al., 1975) and ammonia in the digestate determined by semi-automated colorimetry (Hambleton, 1977). Concentration of crude protein (CP) in the herbage dry matter (105 °C) was calculated as  $N \times 6.25$ . In vitro digestible organic matter (IVDOM) concentration was determined by the two-stage procedure of Tilley and Terry (1963) modified by Moore and Mott (1974), and neutral detergent fiber (NDF) determination followed the procedure described by Golding et al. (1985).

Animals were weighed at the beginning and end of the grazing season and every 28 d in the interim. Shrunk weights were taken after a 16-h feed and water fast. Values reported for average daily gain (ADG) are for tester animals only. Carrying capacity (CC), expressed as number of 350-kg animals  $ha^{-1} d^{-1}$ , was calculated using both testers and grazers. Gain  $ha^{-1}$  was calculated as the product of tester ADG and heifer days  $ha^{-1}$  (CC times number of days of grazing).

Data were subjected to analysis of variance (PROC ANOVA, PROC GLM; SAS Institute Inc., 1989) and mean responses across sampling dates are presented in tables. Graphs are presented that show temporal variation in pasture and animal

responses. For each date (weigh day) the response plotted represents the mean of data collected at the beginning, midpoint, and end of the 28-d period that ends on that date.

## Results and Discussion

### Herbage Nutritive Value

Mean seasonal nutritive value responses are shown in Table 5.1. Florakirk had higher concentrations of CP and was lower in IVDOM and NDF. For both grasses, CP concentrations increased during the first two months of grazing and tended to level off after that at between 120 and 150 g kg<sup>-1</sup> (Fig. 5.1). Fertilization with 56 kg N ha<sup>-1</sup> on 10 June contributed to the increase in CP concentration from 9 June to 7 July. Florakirk herbage maintained a higher CP concentration than Tifton 85 in late spring and throughout the summer but there were no differences between grasses in early autumn. Concentration of IVDOM in Tifton 85 averaged 20 g kg<sup>-1</sup> more than in Florakirk (Table 5.1), but IVDOM was not different between grasses until late September, when Tifton 85 showed an increase to 592 g kg<sup>-1</sup> while Florakirk IVDOM was 519 g kg<sup>-1</sup> (Fig. 5.2). Concentrations of NDF fluctuated around 800 g kg<sup>-1</sup> and varied even less than IVDOM (Fig 5.3). Although differences between grasses were not large, the consistency of the response explains why the seasonal mean NDF concentration was higher in Tifton 85 (Table 5.1). Little unexplained variation (C.V. < 1.75%) in NDF resulted in treatment differences being detected

Table 5.1. Mean concentrations across sampling dates of crude protein (CP), in vitro digestible organic matter (IVDOM), and neutral detergent fiber (NDF) in hand-plucked herbage of Florakirk and Tifton 85 bermudagrasses.

| Grass                       | CP                             | IVDOM | NDF   |
|-----------------------------|--------------------------------|-------|-------|
|                             | ----- g kg <sup>-1</sup> ----- |       |       |
| Florakirk                   | 132                            | 534   | 772   |
| Tifton 85                   | 122                            | 554   | 808   |
| <i>P</i> value <sup>†</sup> | 0.087                          | 0.041 | 0.002 |
| C.V.(%)                     | 3.1                            | 2.0   | 0.8   |

<sup>†</sup> Probability value of a treatment F test.

during each sampling period (Fig. 5.3), with Tifton 85 always showing higher NDF concentrations.

Forage chemical composition and digestibility are influenced markedly by plant age. An increase in NDF associated with decreases in CP and IVDOM concentrations have been reported in warm-season grasses, including bahiagrass, bermudagrass, and digitgrass (Moore, 1973). At initiation of grazing in May, sward height was above the target height, so hand-plucked samples included older herbage with more stem material. This is reflected in the lower CP and IVDOM concentrations during the first period. After the height of the sward was reduced to near 20 cm by grazing, hand-plucked samples contained more young, leafy herbage and CP and IVDOM concentrations increased. Concentrations of NDF were not higher in the more mature forage early in the grazing season than in the leafier material available after the target sward height was reached. Consistently higher

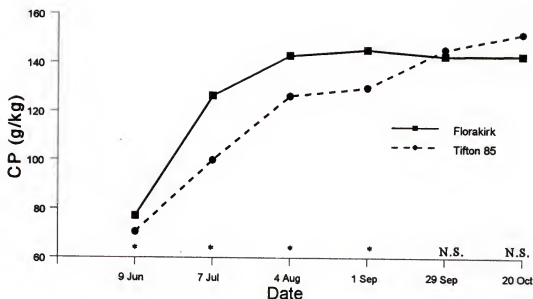


Figure 5.1. Seasonal trend in crude protein (CP) concentration in hand-plucked herbage of Florakirk and Tifton 85 bermudagrasses. Dates are animal weigh days. Symbols above the x-axis indicate results of treatment comparisons (\*,  $P \leq 0.05$ ; N.S., not significant).

NDF concentrations of Tifton 85 were associated with its equal or higher IVDOM than Florakirk. A relatively weak relationship across cultivars between NDF and IVDOM is not unusual for grasses of subtropical or tropical origin like bermudagrass (Moore and Mott, 1973).

In a study similar to the current one, Sollenberger et al. (1988) observed a decline in CP and IVDOM concentrations in 'Pensacola' bahiagrass and 'Floralta' limpograss pastures from early to mid-summer. The decline in CP could, however, be overcome by applications of N fertilizer, which boosted CP concentrations in mid-August. In that study, concentrations of CP and IVDOM in extrusa samples from

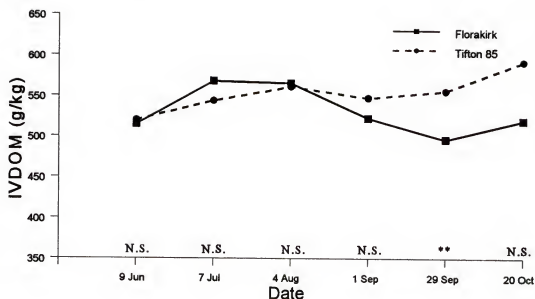


Figure 5.2. Seasonal trend in in vitro digestible organic matter (IVDOM) concentration in hand-plucked herbage of Florakirk and Tifton 85 bermudagrasses. Dates are animal weigh days. Symbols above the x-axis indicate results of treatment comparisons (\*\*,  $P \leq 0.01$ ; N.S., not significant).

fistulated animals (i.e., grazed herbage) were consistently higher than in herbage clipped at soil level. In a study with beef steers stocked continuously on bermudagrass pastures, Hill et al. (1993) found that CP concentrations of extrusa samples of Tifton 85 and Tifton 78 increased from below  $120 \text{ g kg}^{-1}$  in May to above  $150 \text{ g kg}^{-1}$  in July and September. Their findings are consistent with the results of the current study, although their absolute values of CP concentration are higher. The fact that in their study, pastures received  $252 \text{ kg N ha}^{-1}$ , may explain absolute differences. In the same study, Hill et al. (1993) observed values of in vitro digestible dry matter (IVDDM) concentration fluctuating around  $590 \text{ g kg}^{-1}$  and declining by the end of the

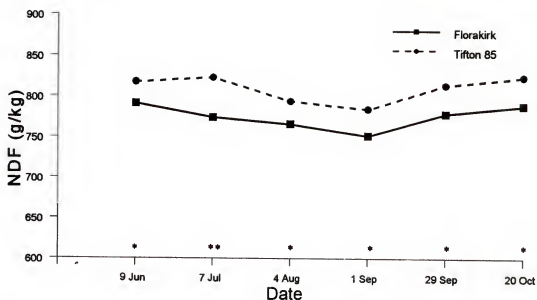


Figure 5.3. Seasonal trend in neutral detergent fiber (NDF) concentration in hand-plucked herbage of Florakirk and Tifton 85 bermudagrasses. Dates are animal weigh days. Symbols above the x-axis indicate results of treatment comparisons (\*\*,  $P \leq 0.01$ ; \*,  $P \leq 0.05$ ).

season. Concentration of CP was similar in both grasses but higher in Tifton 85 at season end, whereas concentration of IVDDM was always higher in Tifton 85, except for the July sampling. Concentration of NDF was higher in Tifton 85 in early season ( $754 \text{ g kg}^{-1}$  vs.  $731 \text{ g kg}^{-1}$  of Tifton 78) but declined to a value similar to that of Tifton 78 ( $712 \text{ g kg}^{-1}$ ) by late season, considerably lower than the values reported in the current study.

#### Pasture Productivity under Grazing and Animal Performance

Total seasonal HAC and mean seasonal growth rate (GR) were 65 and 68% higher, respectively, for Tifton 85 than for Florakirk (Table 5.2). Tifton 85 pastures

Table 5.2. Total seasonal herbage accumulation (HAC) and growth rate (GR) of Florakirk and Tifton 85 bermudagrass pastures.

| Grass                       | HAC (Mg ha <sup>-1</sup> ) | GR (kg DM ha <sup>-1</sup> d <sup>-1</sup> ) |
|-----------------------------|----------------------------|----------------------------------------------|
| Florakirk                   | 8.9                        | 44                                           |
| Tifton 85                   | 14.7                       | 73                                           |
| <i>P</i> value <sup>†</sup> | 0.001                      | 0.001                                        |
| C.V. (%)                    | 7.6                        | 7.5                                          |

<sup>†</sup> Probability value of treatment F test.

accumulated 14.7 Mg ha<sup>-1</sup> and grew at an average rate of 73 kg DM ha<sup>-1</sup> d<sup>-1</sup>, whereas the Florakirk pastures accumulated 8.9 Mg ha<sup>-1</sup> with an average growth rate of 44 kg DM ha<sup>-1</sup> d<sup>-1</sup>. There are no reports in the literature of productivity of either one of these grasses under grazing in a continuous stocking system. Results from small-plot clipping and mob-grazing trials with Florakirk bermudagrass have been reported elsewhere (Chapter 3) and seasonal HAC values of 14 Mg ha<sup>-1</sup> have often been achieved (Mislevy et al., 1995). Under a rotational stocking system (14 d of grazing followed by 28 d of rest), Larbi et al. (1990) reported a 3-yr mean HAC of 12.8 Mg ha<sup>-1</sup> in South Florida for grazing seasons that lasted from May to December. Hill et al. (1993) reported DM yields of up to 18.6 Mg ha<sup>-1</sup> for Tifton 85 in small plot clipping trials.

The greater yielding capacity of Tifton 85 was seen early in the grazing season, when mean HM on Tifton 85 pastures was 3.2 Mg ha<sup>-1</sup>, whereas on Florakirk, mean HM was 2.3 Mg ha<sup>-1</sup> (Fig 5.4). In an attempt to equalize sward

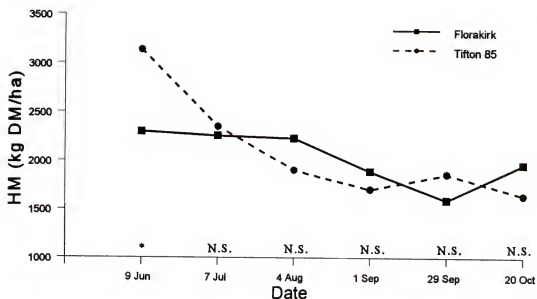


Figure 5.4. Seasonal trend in herbage mass (HM) on Florakirk and Tifton 85 bermudagrass pastures. Dates are animal weigh days. Symbols above the x-axis indicate results of treatment comparisons (\*,  $P \leq 0.05$ ; N.S., not significant).

height across pastures, stocking rate (SR) was higher on Tifton 85 during the first three 28-d periods. In fact, for the period ending on the 7 July weigh day, SR on Tifton 85 was almost twice that of Florakirk (11.8 vs. 6.5 head  $\text{ha}^{-1} \text{d}^{-1}$ ).

Herbage mass differences between grasses ceased by 7 July due to the adjustments in stocking rate (Fig. 5.4) and declined from 2.3  $\text{Mg ha}^{-1}$  to about 1.8  $\text{Mg ha}^{-1}$  through the rest of the grazing season. Because HM of Tifton 85 pastures was initially higher than that of Florakirk, their mean carrying capacity was also higher (Fig. 5.5). Even after HM differences disappeared, SR on Tifton 85 remained higher ( $P < 0.01$ ) for two more 28-d periods due in large part to the higher growth rate of Tifton 85 pastures. In South Florida, Larbi et al. (1990) found that mean carrying

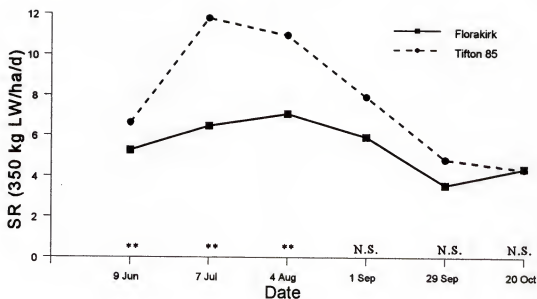


Figure 5.5. Seasonal trend in stocking rate (SR) on Florakirk and Tifton 85 bermudagrass pastures. Dates are animal weigh days. Symbols above the x-axis indicate results of treatment comparisons (\*\*,  $P \leq 0.01$ ; N.S., not significant).

capacity of Florakirk pastures was  $1330 \text{ kg LW ha}^{-1} \text{ d}^{-1}$  (3.8, 350-kg LW animals), which is lower than the mean seasonal carrying capacity of the Florakirk pastures found in the current study of  $5.5 \text{ head ha}^{-1}$ . The mean seasonal carrying capacity of Tifton 85 pastures was  $7.7 \text{ head ha}^{-1}$ .

In variable stocking rate experiments such as the one reported herein, animal numbers are adjusted so that herbage allowance (HAL, kg herbage DM per kg animal LW) remains relatively constant. Adjustments in HAL are often made indirectly in continuously stocked pastures by adjusting other more easily measurable sward attributes such as sward height. Because of variation in sward bulk density among species grazed and season of the year, HAL is an important criterion to supplement

sward height in making stocking decisions (Hutchings et al., 1992). The lag between SR adjustments and the desired shift in HM, makes fluctuations in HAL difficult to avoid. In the current study, Tifton 85 pastures were heavily stocked early in the grazing season (Fig. 5.5) because HM was high. This caused a sharp reduction in HAL, which remained below that on Florakirk pastures through the period that ended on 1 September (Fig. 5.6). This happened despite the fact that mean HM was similar for pastures of both grasses in all 28-d periods (Fig. 5.4).

Average daily gain on the two grasses was not different during any period. The seasonal trend showed highest gains for both grasses in early summer and early autumn (Fig. 5.7). Lowest gains were observed in mid- to late summer and mid-autumn. Average daily gain followed a seasonal pattern more nearly like that of HAL than patterns for nutritive value responses. The absence of a depression in CP or IVDOM during mid-summer suggests that lower ADG during that time was a result of reductions in HAL. For continuously stocked pastures of pearl millet [*Pennisetum glaucum* (L.) R. Br.], McCartor and Rouquette (1977) reported that ADG increased linearly up to an HAL of 1 kg forage DM per kg of animal LW. Further increases in HAL resulted in no further increases in ADG. With the exception of 20 October for Florakirk, lowest ADG in the current study occurred when HAL had dropped to 1 kg kg<sup>-1</sup> or lower. Highest ADG occurred early and late in the grazing season when HAL was in the approximate range of 1.2 to 1.4 kg kg<sup>-1</sup> for both grasses. The differences in HAL between treatments during summer suggest that heifer gains on Tifton 85 could be improved by using somewhat lower stocking rates, specifically those that

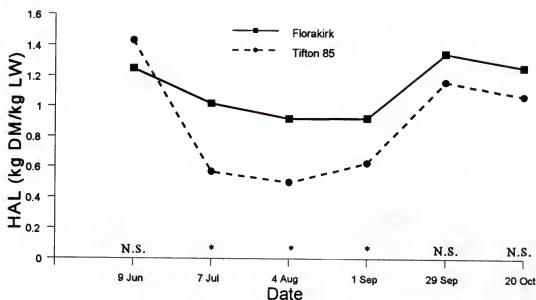


Figure 5.6. Seasonal trend in herbage allowance (HAL) on Florakirk and Tifton 85 bermudagrasses. Dates are animal weigh days. Symbols above the x-axis indicate results of treatment comparisons (\*,  $P \leq 0.05$ ; N.S., not significant).

result in HAL of 1 kg kg<sup>-1</sup> or greater. This conclusion is supported by higher ADG on Tifton 85 when pastures were grazed to maintain an HM of 2400 kg ha<sup>-1</sup> (Hill et al., 1993). The seasonal trends in ADG observed in the current study are similar to those reported for other warm-season grasses. Sollenberger et al. (1988) observed a decline in ADG of yearling steers grazing Floralta limpograss (from approx. 0.36 to 0.18 kg) and Pensacola bahiagrass (from approx. 0.9 to 0.13 kg), from early June to late October. In a study where 'Sarasota' stargrass, 'Ona' stargrass, 'Callie' bermudagrass, and 'Bigalta' limpograss pastures were grazed year-long, Pitman et al. (1984) reported that ADGs dropped from an average of 0.79 to 0.15 kg, from May to August.

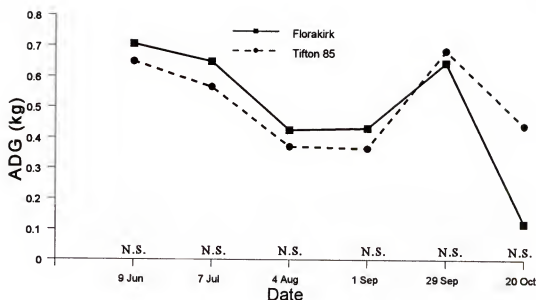


Figure 5.7. Seasonal trend in average daily gain (ADG) of animals grazing on Florakirk and Tifton 85 bermudagrass pastures. Dates are animal weigh days. Symbols above the x-axis indicate results of treatment comparisons (N.S., not significant).

Because the carrying capacity of Tifton 85 was greater than that of Florakirk, gain per hectare was higher on Tifton 85 than on Florakirk pastures (Table 5.3). Hill et al. (1993) reported gains of 789 and 1156 kg ha<sup>-1</sup> on Tifton 78 and Tifton 85 pastures, respectively, due in part to a 38% higher carrying capacity of Tifton 85 pastures. Mean ADG on Florakirk in the current study was higher than that reported by Larbi et al. (1990) (0.38 kg), but liveweight gain ha<sup>-1</sup> was higher (495 kg) in the Larbi et al. (1990) study because of a longer grazing season.

Table 5.3. Mean seasonal average daily gain (ADG) and gain per hectare (GAIN) of animals grazing Florakirk and Tifton 85 bermudagrass pastures.

| Grass                       | ADG (kg animal <sup>-1</sup> ) | GAIN (kg ha <sup>-1</sup> ) |
|-----------------------------|--------------------------------|-----------------------------|
| Florakirk                   | 0.54                           | 447                         |
| Tifton 85                   | 0.51                           | 648                         |
| <i>P</i> value <sup>†</sup> | 0.500                          | 0.092                       |
| C.V. (%)                    | 11.6                           | 20.3                        |

<sup>†</sup> Probability value of treatment F test.

### Summary and Conclusions

Tifton 85 and Florakirk are the most recently released bermudagrass hybrids for the southeastern US cattle industry. A grazing trial was initiated in 1994 to assess their potential and measure forage and animal responses under continuous stocking.

Forage IVDOM averaged 20 g kg<sup>-1</sup> higher for Tifton 85 than Florakirk (554 vs. 534), but Florakirk was higher in CP concentration (132 vs. 122 g kg<sup>-1</sup>), particularly during the first two-thirds of the season. Concentration of NDF was consistently higher in Tifton 85 herbage (808 vs. 772 g kg<sup>-1</sup>).

Total seasonal herbage accumulation and mean pasture growth rate were higher for Tifton 85. This resulted in higher average stocking rate on Tifton 85 pastures than on Florakirk (7.7 vs. 5.5 heifers ha<sup>-1</sup>).

Average daily gain was not different for the two grasses (mean=0.52 kg head<sup>-1</sup> d<sup>-1</sup>) and was lowest from mid-July to mid-September. Because the carrying capacity

of Tifton 85 was higher than that of Florakirk, LW gains were higher from Tifton 85 pastures (648 vs. 447 kg ha<sup>-1</sup>).

Heifer ADG and pasture HAL responses followed similar patterns throughout the season. Changes in ADG were not always consistent with those of nutritive value of hand-plucked herbage. Presence of more mature forage in early season was not detrimental to ADG because HAL was high and there was greater opportunity for selection. Herbage allowances were lower in Tifton 85 pastures than in Florakirk for three 28-d periods in mid-season. Although there were no differences in ADG between grasses during these periods, the lower HAL for Tifton 85 suggests that it may be capable of supporting higher ADGs than were observed. A partial explanation for the lack of differences in ADG between grasses despite lower HAL for Tifton 85 is its higher IVDOM.

Results of this study suggest that both grasses are productive under grazing, although HAC was considerably higher for Tifton 85 (14.7 Mg ha<sup>-1</sup>) than for Florakirk (8.9 Mg ha<sup>-1</sup>). Lower HAC for Florakirk was due in part to stand loss that occurred in some pastures in late summer and early autumn, forcing an early termination of grazing. Target sward height on those pastures was maintained by reducing stocking rates in late season. One of the Florakirk experimental units in a wetter area was invaded by vaseygrass (*Paspalum urvillei* Steud.) while another unit showed reduced herbage mass and a localized oval-shaped area with dead plants. This area spread consistently through autumn despite efforts to reduce stress by taking animals off the pasture. Infection by *Helminthosporium* spp. was diagnosed on

samples of vegetative material. Tifton 85 also was affected but to a much smaller extent, and a very high percentage of plants in the affected areas survived. Mislevy et al. (1995) suggested that this disease is associated with tall swards and underutilized forage, and recommended that regrowth periods for Florakirk under rotational stocking or hay harvest not exceed 4 to 5 wk. Florakirk pastures in the current study did not have large quantities of unutilized forage, and the *Helminthosporium spp.* is not generally lethal to bermudagrass, so the specific cause of the stand loss is unknown.

Conclusions based on 1 yr of study should be considered preliminary in nature. These data suggest, however, that under continuous stocking in North Florida, there are advantages in plant productivity, digestibility, and possibly persistence for Tifton 85 over Florakirk. The data provide evidence that HAL on Tifton 85 pastures should be in the range of 1.0 to 1.4 kg of forage per kg of animal LW to maintain ADG of 0.5 kg or greater. Longer term evaluation is needed to assess the persistence of Tifton 85 in the region. Florakirk demonstrated good persistence after 2 yr under a wide range of grazing treatments in a companion study (Chapters 3 and 4), but persistence was poor under continuous stocking in this experiment. To this point, it has not been possible to determine if Florakirk stand losses observed in this study were in response to grazing management, disease, or a combination of these factors with other attributes of the growing environment.

## CHAPTER 6

### GENERAL CONCLUSIONS

The purpose of this chapter is to summarize findings of experiments described in Chapters 3 through 5 and to highlight the most important conclusions from the research. Additionally, practical implications and future research needs will be discussed.

These experiments were designed to quantify the potential of 'Florakirk' and 'Tifton 85' bermudagrasses under grazing in North Central Florida. Florakirk and Tifton 85 are the two most recent bermudagrass releases with potential in the Lower South, and their successful adoption could have an impact on the livestock industry of the region.

Two major studies were conducted. In Chapters 3 and 4, Florakirk bermudagrass responses to nine combinations of grazing frequency (7, 21, and 35 d between grazings) and intensity (8, 16, and 24 cm of postgraze stubble) were studied. In both years of this mob-grazing trial (June to October in 1993 and May to October in 1994) lowest seasonal forage yields were associated with intermediate grazing frequencies (21 d). Both the 7 d and the 35 d frequencies gave greater yields than did the 21-d treatments. In 1993, pastures that were grazed every 7 d to a 24-cm stubble gave the highest yields ( $13.1 \text{ Mg ha}^{-1}$ ) and this combination of frequency and intensity

was also favorable to high yields in 1994 ( $16.2 \text{ Mg ha}^{-1}$ ). Equally high yields in 1994 were observed for pastures grazed every 35 d to 24 cm ( $17 \text{ Mg ha}^{-1}$ ).

Although the relatively high yields observed for pastures grazed at the 7-d frequency find some rationale in physiology and morphology of grass growth under grazing, there is a possibility that 7-d treatment yields were overestimated. Because of the small size of the experimental units ( $200 \text{ m}^2$ ) and the magnitude of sampling errors in relation to weekly herbage growth in the 7-d treatments, cages were used instead of weekly sampling to measure pasture growth on pastures under the 7-d grazing frequency treatment. This means that plants growing inside the cages did not experience exactly the same environment as did those outside the cages, despite cages being rotated every 3 wk to minimize differences. Areas protected from grazing probably had higher growth rates than areas outside the cages because plants inside cages benefitted from greater leaf area during the growth period. This likely resulted in an overestimation of yields on the 7-d treatments. It is generally true that close and frequent grazing results in lower seasonal herbage yields than leniently grazed swards. For this particular experiment, the use of cages did not seem to be fully adequate and yield data from the frequently grazed pastures (7 d grazing cycle) cannot be considered conclusive. The relative yields from pastures grazed every 21 and 35 d are more accurate and are consistent with the literature.

The fact that organic matter digestibility and crude protein concentrations varied little across grazing treatments in both years of the study, suggests that the differences found may not have great biological significance. There was, however, a

general trend for lower digestible organic matter and lower crude protein concentration at the longer grazing intervals (i.e., lower grazing frequencies). This is explained by the effect of maturity on digestibility and crude protein concentration.

The main practical implication of these findings is that animals requiring higher levels of nutrition, such as replacement heifers, would benefit from short pasture rest periods in a rotational system, or from a continuous stocking system. With adequate fertilizer inputs, this type of management would provide forage of high nutritive value with good gains per head, although liveweight gain per unit area will not be maximized. For mature cows, a rotational stocking system with approximately 5 wk between grazings and an intermediate postgraze stubble (15 to 20 cm) may be best as it will allow for high forage yields and consequently high stocking rates.

In the same mob-grazing study, persistence-related responses of Florakirk bermudagrass to grazing management were studied (Chapter 4). Although the levels of carbohydrate stored in rhizomes (the main storage organs of this bermudagrass) declined considerably from the end of the first to the end of the second grazing season, the effect of grazing management was relatively small and not consistent across years. Even for the most frequently and closely grazed pastures, plant vigor and overall stand condition were not negatively affected. In fact, short intervals between grazings seem to have induced changes in growth habit which overcame possible detrimental effects. By the end of the first growing season, visual evaluation indicated that frequent and close grazing caused plants to grow close to the soil surface, resulting in greater ground coverage and tillering. It is possible that under

these circumstances, residual leaf area became more important to regrowth than were carbohydrate reserves and this could partially explain lower rhizome carbohydrate concentrations. There is a need, however, for further investigation in order to assess the consequences of this phenomenon on long-term persistence, and on winter survival especially if utilization of Florakirk at higher latitudes is desired.

In the second study (Chapter 5), plant and animal responses were studied in a grazing trial where Florakirk and Tifton 85 pastures were stocked continuously from May to October with yearling beef heifers, using a variable stocking rate. Tifton 85 had greater growth rates (73 vs. 44 kg DM ha<sup>-1</sup> d<sup>-1</sup>) and seasonal forage yield (14.7 vs. 8.9 Mg ha<sup>-1</sup>) than Florakirk, and Tifton 85 herbage had a higher concentration of digestible organic matter (554 vs. 534 g kg<sup>-1</sup>). Average crude protein concentration in Florakirk herbage was 132 g kg<sup>-1</sup> compared with 122 g kg<sup>-1</sup> of Tifton 85. Over the season, animal performance (daily liveweight gain) was more influenced by herbage allowance than by herbage nutritive value. Whereas heifer average daily gain did not differ between grasses (avg. 0.52 kg), greater forage yields on Tifton 85 pastures allowed for heavier stocking and consequently greater liveweight gains per unit area.

At the end of the first year of the grazing trial, one Florakirk pasture showed signs of severe deterioration. An area of browned plants spread rapidly across the pasture and these plants did not recover despite efforts to reduce stress by terminating grazing early. Although infection by *Helminthosporium spp.* was diagnosed, another factor or combination of factors, yet to be identified, was probably responsible for the stand loss. Tifton 85 was also affected but the extent of the deterioration was much

smaller and did not compromise the condition of the stand. In another Florakirk pasture, located in a wetter area, severe weed invasion was noticed. Because Florakirk did not persist well under continuous stocking, it may be better utilized under rotational stocking or as a hay crop.

This research has provided a preliminary appreciation for the potential of two new bermudagrasses for the North Florida beef cattle industry. Definitive recommendations concerning management for pasture productivity and longevity will require a continuation of the evaluation process.

## APPENDIX

Table A.1. Pre- (PRE) and postgraze (POST) herbage mass for each grazing (6 for GC=7 and GC=21; 4 for GC=35) and total seasonal herbage accumulation (HAC) in 1993 for treatment combinations of grazing cycle (GC) and stubble height (SH). Data are reported in Chapter 3.

| GC    | SH     | REP | PRE1                   | POST1 | PRE2 | POST2 | PRE3 | POST3 | PRE4 | POST4 | PRE5 | POST5 | PRE6 | POST6 | HAC   |
|-------|--------|-----|------------------------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|-------|
| - d - | - cm - |     | kg DM ha <sup>-1</sup> |       |      |       |      |       |      |       |      |       |      |       |       |
| 7     | 8      | 1   | 2480                   | 1448  | 2110 | 1467  | 1850 | 1459  | 2600 | 1515  | 2380 | 1719  | 3830 | 2007  | 7643  |
| 7     | 8      | 2   | 3462                   | 1347  | 1880 | 2147  | 2350 | 1733  | 2650 | 1635  | 2750 | 1853  | 3590 | 1918  | 7967  |
| 7     | 16     | 1   | 2698                   | 1783  | 2310 | 2301  | 3480 | 1971  | 3550 | 1817  | 3690 | 2161  | 3960 | 2393  | 9655  |
| 7     | 16     | 2   | 3616                   | 1830  | 3220 | 2503  | 3480 | 2390  | 4480 | 2082  | 4390 | 2645  | 4390 | 2684  | 12124 |
| 7     | 24     | 1   | 3641                   | 2776  | 4100 | 3197  | 5920 | 2363  | 4070 | 2913  | 6230 | 3588  | 4490 | 3566  | 13613 |
| 7     | 24     | 2   | 4263                   | 3015  | 4150 | 3418  | 6310 | 2623  | 0    | 0     | 5490 | 3476  | 4630 | 3728  | 12311 |
| 21    | 8      | 1   | 2259                   | 1277  | 2030 | 1769  | 3149 | 1895  | 2441 | 1823  | 2365 | 1993  | 3314 | 2130  | 6801  |
| 21    | 8      | 2   | 3588                   | 1504  | 2365 | 2561  | 3194 | 2203  | 2673 | 1844  | 2329 | 1999  | 3001 | 1937  | 7039  |
| 21    | 16     | 1   | 2645                   | 1781  | 2981 | 2475  | 3585 | 2684  | 3594 | 2539  | 3384 | 2880  | 3446 | 2774  | 7812  |
| 21    | 16     | 2   | 3599                   | 1965  | 3448 | 3113  | 4624 | 2281  | 3168 | 2413  | 3308 | 2466  | 3082 | 2533  | 8992  |
| 21    | 24     | 1   | 3602                   | 2847  | 4056 | 3415  | 4722 | 3233  | 4184 | 3658  | 4470 | 4078  | 4257 | 3762  | 8060  |
| 21    | 24     | 2   | 4322                   | 2824  | 4945 | 3188  | 5253 | 3261  | 4596 | 3865  | 5589 | 3972  | 4436 | 3622  | 12032 |
| 35    | 8      | 1   | 2385                   | 1406  | 4014 | 1711  | 3678 | 2391  | 4237 | 2139  | 0    | 0     | 0    | 0     | 8807  |
| 35    | 8      | 2   | 2956                   | 1224  | 3205 | 2102  | 3308 | 2265  | 3700 | 2391  | 0    | 0     | 0    | 0     | 7579  |
| 35    | 16     | 1   | 2810                   | 1683  | 4218 | 2483  | 4475 | 3560  | 4660 | 2889  | 0    | 0     | 0    | 0     | 8438  |
| 35    | 16     | 2   | 3790                   | 1705  | 4042 | 2270  | 4453 | 3737  | 4783 | 3252  | 0    | 0     | 0    | 0     | 9356  |
| 35    | 24     | 1   | 4134                   | 2735  | 4764 | 3440  | 4959 | 3930  | 5441 | 2833  | 0    | 0     | 0    | 0     | 9193  |
| 35    | 24     | 2   | 4205                   | 3015  | 6210 | 3613  | 5197 | 4240  | 5091 | 3398  | 0    | 0     | 0    | 0     | 9835  |

Table A.2. Pre- (PRE) and postgraze (POST) herbage mass for each grazing (7 for GC=7 and GC=21; 5 for GC=35), and total seasonal herbage accumulation (HAC) in 1994 for treatment combinations of grazing cycle (GC) and stubble height (SH). Data are reported in Chapter 3.

| GC | SH | REP | PRE1 | POST1 | PRE2 | POST2 | PRE3 | POST3 | PRE4 | POST4 | PRE5 | POST5 | PRE6 | POST6 | PRE7 | POST7 | HAC                    |
|----|----|-----|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------------------------|
| -  | -  | -   | -    | -     | -    | -     | -    | -     | -    | -     | -    | -     | -    | -     | -    | -     | -                      |
|    |    |     |      |       |      |       |      |       |      |       |      |       |      |       |      |       | kg DM ha <sup>-1</sup> |
| 7  | 8  | 1   | 4945 | 2801  | 2930 | 2813  | 4800 | 2724  | 2500 | 2484  | 5350 | 3118  | 3490 | 2712  | 4203 | 2549  | 11567                  |
| 7  | 8  | 2   | 4674 | 2442  | 2840 | 2975  | 3740 | 2619  | 2860 | 2330  | 4660 | 2581  | 3400 | 2473  | 3890 | 2666  | 10645                  |
| 7  | 16 | 1   | 4798 | 3778  | 5020 | 3921  | 5370 | 4056  | 5350 | 4180  | 6090 | 4454  | 6460 | 4566  | 6247 | 4076  | 14379                  |
| 7  | 16 | 2   | 5227 | 3342  | 4720 | 3960  | 5330 | 3844  | 6220 | 4358  | 6480 | 4566  | 6670 | 4300  | 6426 | 4346  | 16704                  |
| 7  | 24 | 1   | 5439 | 4531  | 7930 | 5339  | 6550 | 5184  | 6410 | 5149  | 7550 | 5454  | 9150 | 6150  | 6365 | 5910  | 17587                  |
| 7  | 24 | 2   | 6096 | 4508  | 4710 | 5524  | 5610 | 5068  | 6370 | 5667  | 8310 | 5265  | 7450 | 5601  | 8456 | 5458  | 15368                  |
| 21 | 8  | 1   | 4975 | 2811  | 3497 | 3167  | 5829 | 3315  | 3754 | 3305  | 4948 | 3233  | 3899 | 3183  | 3975 | 3391  | 12549                  |
| 21 | 8  | 2   | 5153 | 2827  | 3523 | 3454  | 5526 | 3424  | 4338 | 3374  | 4922 | 3045  | 3771 | 3206  | 3959 | 3358  | 11860                  |
| 21 | 16 | 1   | 5618 | 4206  | 5724 | 4717  | 6360 | 4526  | 5961 | 5041  | 6278 | 5179  | 5945 | 4394  | 5120 | 4519  | 12942                  |
| 21 | 16 | 2   | 5427 | 4150  | 6103 | 4510  | 6162 | 4872  | 5470 | 5173  | 6275 | 4460  | 5575 | 4381  | 5288 | 4602  | 10954                  |
| 21 | 24 | 1   | 5730 | 5173  | 6971 | 5997  | 6723 | 5344  | 7630 | 5813  | 7264 | 5948  | 7033 | 5816  | 6674 | 6202  | 13935                  |
| 21 | 24 | 2   | 6176 | 4810  | 6928 | 6119  | 6961 | 5714  | 8040 | 5367  | 6713 | 5305  | 6294 | 5608  | 6136 | 5229  | 14324                  |
| 35 | 8  | 1   | 5486 | 3239  | 5915 | 3672  | 5476 | 3388  | 5466 | 3091  | 4701 | 3144  | 0    | 0     | 0    | 0     | 13654                  |
| 35 | 8  | 2   | 5552 | 3051  | 5701 | 3685  | 5565 | 3381  | 5057 | 3325  | 4889 | 3167  | 0    | 0     | 0    | 0     | 13321                  |
| 35 | 16 | 1   | 5734 | 4421  | 7809 | 3992  | 7225 | 4546  | 7225 | 4008  | 5631 | 4859  | 0    | 0     | 0    | 0     | 16656                  |
| 35 | 16 | 2   | 5328 | 3912  | 7396 | 4239  | 6822 | 4965  | 6499 | 4503  | 5163 | 5021  | 0    | 0     | 0    | 0     | 13588                  |
| 35 | 24 | 1   | 6868 | 5057  | 9095 | 4513  | 8132 | 5806  | 7555 | 6004  | 7307 | 5618  | 0    | 0     | 0    | 0     | 17577                  |
| 35 | 24 | 2   | 6852 | 5206  | 8445 | 5057  | 8330 | 5410  | 7423 | 5879  | 6522 | 5064  | 0    | 0     | 0    | 0     | 16020                  |

Table A.3. Crude protein (CP) concentration in hand-plucked herbage sampled pregraze from treatment combinations of grazing cycle (GC) and stubble height (SH) in 1993. Data are reported in Chapter 3.

| GC    | SH     | REP | CP 1 | CP 2 | CP 3               | CP 4 | CP 5 | CP 6 |
|-------|--------|-----|------|------|--------------------|------|------|------|
| - d - | - cm - |     |      |      | g kg <sup>-1</sup> |      |      |      |
| 7     | 8      | 1   | 95   | 120  | 141                | 145  | —    | 101  |
| 7     | 8      | 2   | 75   | —    | 135                | 116  | —    | 84   |
| 7     | 16     | 1   | 108  | 86   | —                  | 132  | 151  | —    |
| 7     | 16     | 2   | 91   | 83   | —                  | 116  | 145  | —    |
| 7     | 24     | 1   | 105  | 146  | 95                 | 108  | 112  | 79   |
| 7     | 24     | 2   | 82   | 182  | 90                 | 107  | 103  | 97   |
| 21    | 8      | 1   | 97   | 137  | 136                | 94   | 105  | 148  |
| 21    | 8      | 2   | 84   | 124  | 126                | 98   | 120  | 115  |
| 21    | 16     | 1   | 98   | 113  | 121                | 93   | 152  | 85   |
| 21    | 16     | 2   | 98   | 96   | 110                | 93   | 158  | 77   |
| 21    | 24     | 1   | 108  | 92   | 105                | 130  | 151  | 74   |
| 21    | 24     | 2   | 120  | 116  | 111                | 137  | 148  | 87   |
| 35    | 8      | 1   | 105  | 75   | 121                | 107  | —    | —    |
| 35    | 8      | 2   | 96   | 75   | 87                 | 115  | —    | —    |
| 35    | 16     | 1   | 111  | 124  | 103                | 94   | —    | —    |
| 35    | 16     | 2   | 88   | 122  | 108                | 78   | —    | —    |
| 35    | 24     | 1   | 101  | —    | 85                 | 101  | —    | —    |
| 35    | 24     | 2   | 93   | 118  | 96                 | 81   | —    | —    |

Table A.4. Crude protein (CP) concentration in hand-plucked herbage sampled pregraze from treatment combinations of grazing cycle (GC) and stubble height (SH) in 1994. Data are reported in Chapter 3.

| GC    | SH     | REP | CP 1 | CP 2 | CP 3 | CP 4               | CP 5 | CP 6 | CP 7 |
|-------|--------|-----|------|------|------|--------------------|------|------|------|
| - d - | - cm - |     |      |      |      | g kg <sup>-1</sup> |      |      |      |
| 7     | 8      | 1   | 79   | 160  | 128  | 96                 | 144  | 184  | 128  |
| 7     | 8      | 2   | 97   | 164  | 104  | 102                | 150  | 152  | 140  |
| 7     | 16     | 1   | 83   | 177  | 100  | 187                | 80   | 159  | 148  |
| 7     | 16     | 2   | 93   | 147  | 89   | 148                | 67   | 168  | 146  |
| 7     | 24     | 1   | 89   | 145  | 70   | 185                | 104  | 155  | 132  |
| 7     | 24     | 2   | 92   | 155  | 88   | 183                | 93   | 117  | 104  |
| 21    | 8      | 1   | 80   | 183  | 99   | 90                 | 146  | 169  | 157  |
| 21    | 8      | 2   | 90   | 176  | 110  | 118                | 145  | 178  | 153  |
| 21    | 16     | 1   | 76   | 166  | 69   | 151                | 110  | 170  | 172  |
| 21    | 16     | 2   | 91   | 145  | 60   | 178                | 134  | 169  | 171  |
| 21    | 24     | 1   | 82   | 141  | 110  | 190                | 118  | 168  | 142  |
| 21    | 24     | 2   | 94   | 140  | 94   | 169                | 130  | 122  | 147  |
| 35    | 8      | 1   | 85   | 126  | 149  | 144                | 127  | —    | —    |
| 35    | 8      | 2   | 89   | 127  | 143  | 141                | 102  | —    | —    |
| 35    | 16     | 1   | 76   | 90   | 153  | 148                | 125  | —    | —    |
| 35    | 16     | 2   | 93   | 98   | 146  | 137                | 122  | —    | —    |
| 35    | 24     | 1   | 79   | 68   | 129  | 144                | 164  | —    | —    |
| 35    | 24     | 2   | 95   | 54   | 128  | 161                | 154  | —    | —    |

Table A.5. In vitro digestible organic matter (IVDOM) concentration in hand-plucked herbage sampled pregraze from treatment combinations of grazing cycle (GC) and stubble height (SH) in 1993. Data are reported in Chapter 3.

| GC    | SH     | REP | IVDOM 1                        | IVDOM 2 | IVDOM 3 | IVDOM 4 | IVDOM 5 | IVDOM 6 |
|-------|--------|-----|--------------------------------|---------|---------|---------|---------|---------|
| - d - | - cm - |     | ----- g kg <sup>-1</sup> ----- |         |         |         |         |         |
| 7     | 8      | 1   | 618                            | 677     | 651     | 651     | —       | 622     |
| 7     | 8      | 2   | 544                            | —       | 652     | 607     | —       | 595     |
| 7     | 16     | 1   | 634                            | 593     | —       | 634     | 691     | —       |
| 7     | 16     | 2   | 603                            | 612     | —       | 621     | 666     | —       |
| 7     | 24     | 1   | 623                            | 641     | 594     | 626     | 630     | 547     |
| 7     | 24     | 2   | 612                            | 722     | 586     | 658     | 618     | 590     |
| 21    | 8      | 1   | 619                            | 674     | 666     | 574     | 635     | 669     |
| 21    | 8      | 2   | 588                            | 676     | 665     | 587     | 697     | 654     |
| 21    | 16     | 1   | 623                            | 680     | 650     | 596     | 639     | 584     |
| 21    | 16     | 2   | 602                            | 657     | 653     | 576     | 689     | 569     |
| 21    | 24     | 1   | 614                            | 604     | 666     | 652     | 649     | 489     |
| 21    | 24     | 2   | 620                            | 651     | 680     | 656     | 657     | 507     |
| 35    | 8      | 1   | 756                            | 595     | 638     | 627     | —       | —       |
| 35    | 8      | 2   | 625                            | 647     | 585     | 660     | —       | —       |
| 35    | 16     | 1   | 645                            | 672     | 629     | 620     | —       | —       |
| 35    | 16     | 2   | 605                            | 693     | 642     | 583     | —       | —       |
| 35    | 24     | 1   | 596                            | —       | 547     | 568     | —       | —       |
| 35    | 24     | 2   | 598                            | 647     | 620     | 545     | —       | —       |

Table A.6. In vitro digestible organic matter (IVDOM) concentration in hand-plucked herbage sampled pregraze from treatment combinations of grazing cycle (GC) and stubble height (SH) in 1994. Data are reported in Chapter 3.

| GC    | SH     | REP | IVDOM 1                        | IVDOM 2 | IVDOM 3 | IVDOM 4 | IVDOM 5 | IVDOM 6 | IVDOM 7 |
|-------|--------|-----|--------------------------------|---------|---------|---------|---------|---------|---------|
| - d - | - cm - |     | ----- g kg <sup>-1</sup> ----- |         |         |         |         |         |         |
| 7     | 8      | 1   | 582                            | 543     | 600     | 525     | 613     | 584     | 615     |
| 7     | 8      | 2   | 618                            | 592     | 562     | 502     | 625     | 545     | 592     |
| 7     | 16     | 1   | 569                            | 655     | 506     | 616     | 560     | 616     | 537     |
| 7     | 16     | 2   | 595                            | 601     | 518     | 529     | 547     | 590     | 580     |
| 7     | 24     | 1   | 552                            | 571     | 538     | 638     | 536     | 581     | 515     |
| 7     | 24     | 2   | 566                            | 594     | 479     | 634     | 531     | 429     | 446     |
| 21    | 8      | 1   | 577                            | 628     | 592     | 594     | 623     | 595     | 625     |
| 21    | 8      | 2   | 605                            | 605     | 584     | 568     | 634     | 607     | 635     |
| 21    | 16     | 1   | 561                            | 641     | 541     | 581     | 589     | 630     | 650     |
| 21    | 16     | 2   | 599                            | 613     | 581     | 600     | 576     | 607     | 608     |
| 21    | 24     | 1   | 550                            | 638     | 563     | 667     | 550     | 586     | 576     |
| 21    | 24     | 2   | 554                            | 620     | 547     | 616     | 503     | 522     | 572     |
| 35    | 8      | 1   | 589                            | 606     | 544     | 549     | 571     | —       | —       |
| 35    | 8      | 2   | 623                            | 589     | 575     | 517     | 601     | —       | —       |
| 35    | 16     | 1   | 589                            | 576     | 598     | 548     | 591     | —       | —       |
| 35    | 16     | 2   | 592                            | 536     | 591     | 534     | 587     | —       | —       |
| 35    | 24     | 1   | 554                            | 539     | 562     | 525     | 626     | —       | —       |
| 35    | 24     | 2   | 549                            | 515     | 587     | 529     | 644     | —       | —       |

Table A.7. Neutral detergent fiber (NDF) concentration in hand-plucked herbage sampled pregraze from treatment combinations of grazing cycle (GC) and stubble height (SH) in 1993. Data are reported in Chapter 3.

| GC    | SH     | REP | NDF 1 | NDF 2 | NDF 3 | NDF 4 | NDF 5 | NDF 6 |
|-------|--------|-----|-------|-------|-------|-------|-------|-------|
| - d - | - cm - |     |       |       |       |       |       |       |
| 7     | 8      | 1   | 812   | 799   | 817   | 818   | —     | 844   |
| 7     | 8      | 2   | 797   | —     | 815   | 800   | —     | 808   |
| 7     | 16     | 1   | 812   | 816   | —     | 830   | 780   | —     |
| 7     | 16     | 2   | 838   | 793   | —     | 803   | 769   | —     |
| 7     | 24     | 1   | 850   | 784   | 856   | 812   | 794   | 840   |
| 7     | 24     | 2   | 812   | 816   | 820   | 793   | 789   | 851   |
| 21    | 8      | 1   | 818   | 777   | 840   | 811   | 776   | 834   |
| 21    | 8      | 2   | 837   | 785   | 815   | 820   | 744   | 783   |
| 21    | 16     | 1   | 827   | 781   | 863   | 810   | 789   | 806   |
| 21    | 16     | 2   | 834   | 785   | 818   | 827   | 737   | 796   |
| 21    | 24     | 1   | 844   | 809   | 815   | 821   | 797   | 840   |
| 21    | 24     | 2   | 844   | 767   | 827   | 816   | 802   | 835   |
| 35    | 8      | 1   | 785   | 810   | 825   | 804   | —     | —     |
| 35    | 8      | 2   | 813   | 817   | 812   | 794   | —     | —     |
| 35    | 16     | 1   | 812   | 831   | 834   | 808   | —     | —     |
| 35    | 16     | 2   | 843   | 812   | 838   | 803   | —     | —     |
| 35    | 24     | 1   | 862   | —     | 794   | 833   | —     | —     |
| 35    | 24     | 2   | 826   | 830   | 775   | 831   | —     | —     |

Table A.8. Neutral detergent fiber (NDF) concentration in hand-plucked herbage sampled pregraze from treatment combinations of grazing cycle (GC) and stubble height (SH) in 1994. Data are reported in Chapter 3.

| GC    | SH     | REP | NDF 1 | NDF 2 | NDF 3 | NDF 4 | NDF 5 | NDF 6 | NDF 7 |
|-------|--------|-----|-------|-------|-------|-------|-------|-------|-------|
| - d - | - cm - |     |       |       |       |       |       |       |       |
| 7     | 8      | 1   | 745   | 778   | 761   | 793   | 781   | 804   | 755   |
| 7     | 8      | 2   | 725   | 754   | 756   | 795   | 777   | 798   | 747   |
| 7     | 16     | 1   | 731   | 769   | 742   | 754   | 799   | 797   | 763   |
| 7     | 16     | 2   | 733   | 795   | 803   | 744   | 770   | 755   | 787   |
| 7     | 24     | 1   | 731   | 776   | 769   | 753   | 763   | 753   | 787   |
| 7     | 24     | 2   | 777   | 801   | 788   | 754   | 806   | 760   | 755   |
| 21    | 8      | 1   | 745   | 756   | 766   | 789   | 761   | 738   | 768   |
| 21    | 8      | 2   | 749   | 756   | 741   | 770   | 768   | 780   | 767   |
| 21    | 16     | 1   | 742   | 758   | 739   | 770   | 755   | 777   | 748   |
| 21    | 16     | 2   | 743   | 769   | 731   | 761   | 795   | 761   | 776   |
| 21    | 24     | 1   | 755   | 760   | 785   | 766   | 806   | 735   | 748   |
| 21    | 24     | 2   | 781   | 734   | 798   | 764   | 787   | 746   | 755   |
| 35    | 8      | 1   | 760   | 788   | 705   | 789   | 774   | —     | —     |
| 35    | 8      | 2   | 740   | 737   | 779   | 802   | 757   | —     | —     |
| 35    | 16     | 1   | 736   | 763   | 785   | 788   | 767   | —     | —     |
| 35    | 16     | 2   | 744   | 759   | 784   | 815   | 771   | —     | —     |
| 35    | 24     | 1   | 746   | 738   | 766   | 751   | 744   | —     | —     |
| 35    | 24     | 2   | 769   | 753   | 760   | 757   | 714   | —     | —     |

Table A.9. Pasture botanical composition (expressed as % Florakirk in clipped herbage samples) for treatment combinations of grazing cycle (GC) and stubble height (SH) measured pregraze at the last grazing of the season in 1993 and 1994. Data are reported in Chapter 4.

| GC    | SH     | REP | 1993          | 1994 |
|-------|--------|-----|---------------|------|
| - d - | - cm - |     | ----- % ----- |      |
| 7     | 8      | 1   | 99            | 100  |
| 7     | 8      | 2   | 100           | 100  |
| 7     | 16     | 1   | 99            | 97   |
| 7     | 16     | 2   | 100           | 97   |
| 7     | 24     | 1   | 98            | 96   |
| 7     | 24     | 2   | 99            | 100  |
| 21    | 8      | 1   | 93            | 100  |
| 21    | 8      | 2   | 100           | 100  |
| 21    | 16     | 1   | 99            | 100  |
| 21    | 16     | 2   | 99            | 100  |
| 21    | 24     | 1   | 100           | 99   |
| 21    | 24     | 2   | 100           | 99   |
| 35    | 8      | 1   | 100           | 100  |
| 35    | 8      | 2   | 87            | 100  |
| 35    | 16     | 1   | 99            | 100  |
| 35    | 16     | 2   | 99            | 100  |
| 35    | 24     | 1   | 98            | 97   |
| 35    | 24     | 2   | 100           | 99   |

Table A.10. Canopy light interception measured pre- (LIPRE) and postgraze (LIPOST) for treatment combinations of grazing cycle (GC) and stubble height (SH) in 1993 and 1994. Data are reported in Chapter 4 and are means of measurements taken for two mid-season grazings.

| GC    | SH     | REP | LIPRE         |      | LIPOST |      |
|-------|--------|-----|---------------|------|--------|------|
|       |        |     | 1993          | 1994 | 1993   | 1994 |
| - d - | - cm - |     | ----- % ----- |      |        |      |
| 7     | 8      | 1   | 55            | 57   | 43     | 39   |
| 7     | 8      | 2   | 54            | 45   | 48     | 37   |
| 7     | 16     | 1   | 55            | 74   | 38     | 77   |
| 7     | 16     | 2   | 64            | 68   | 51     | 77   |
| 7     | 24     | 1   | 87            | 84   | 80     | 87   |
| 7     | 24     | 2   | 85            | 82   | 75     | 82   |
| 21    | 8      | 1   | 76            | 66   | 44     | 32   |
| 21    | 8      | 2   | 72            | 69   | 54     | 31   |
| 21    | 16     | 1   | 82            | 83   | 53     | 63   |
| 21    | 16     | 2   | 82            | 83   | 44     | 72   |
| 21    | 24     | 1   | 89            | 91   | 70     | 83   |
| 21    | 24     | 2   | 85            | 89   | 81     | 79   |
| 35    | 8      | 1   | 83            | 90   | 28     | 26   |
| 35    | 8      | 2   | 68            | 85   | 31     | 23   |
| 35    | 16     | 1   | 85            | 94   | 56     | 50   |
| 35    | 16     | 2   | 87            | 91   | 65     | 58   |
| 35    | 24     | 1   | 87            | 95   | 77     | 76   |
| 35    | 24     | 2   | 92            | 93   | 81     | 78   |

Table A.11. Weight of plant fractions for treatment combinations of grazing cycle (GC) and stubble height (SH) sampled postgraze at the last grazing in 1993 and 1994. Data are reported in Chapter 4. TOPSTUB=top of stubble, BASESTUB=base of stubble, RHIZOME=roots and rhizomes.

| GC    | SH     | REP | 1993                            |          |         | 1994    |          |         |
|-------|--------|-----|---------------------------------|----------|---------|---------|----------|---------|
|       |        |     | TOPSTUB                         | BASESTUB | RHIZOME | TOPSTUB | BASESTUB | RHIZOME |
| - d - | - cm - |     | ----- g OM m <sup>2</sup> ----- |          |         |         |          |         |
| 7     | 8      | 1   | 109                             | 308      | 867     | 49      | 296      | 754     |
| 7     | 8      | 2   | 123                             | 180      | 638     | 91      | 247      | 767     |
| 7     | 16     | 1   | 282                             | 263      | 939     | 203     | 275      | 528     |
| 7     | 16     | 2   | 251                             | 152      | 621     | 198     | 284      | 713     |
| 7     | 24     | 1   | 369                             | 214      | 551     | 400     | 252      | 529     |
| 7     | 24     | 2   | 321                             | 264      | 437     | 402     | 318      | 575     |
| 21    | 8      | 1   | 129                             | 155      | 329     | 109     | 415      | 986     |
| 21    | 8      | 2   | 122                             | 77       | 570     | 63      | 257      | 761     |
| 21    | 16     | 1   | 178                             | 204      | 686     | 214     | 271      | 642     |
| 21    | 16     | 2   | 239                             | 286      | 914     | 141     | 213      | 553     |
| 21    | 24     | 1   | 332                             | 239      | 438     | 262     | 191      | 277     |
| 21    | 24     | 2   | 429                             | 271      | 645     | 290     | 236      | 474     |
| 35    | 8      | 1   | 137                             | 203      | 952     | 40      | 205      | 538     |
| 35    | 8      | 2   | 216                             | 210      | 1110    | 46      | 236      | 893     |
| 35    | 16     | 1   | 191                             | 166      | 641     | 181     | 231      | 664     |
| 35    | 16     | 2   | 203                             | 186      | 560     | 173     | 214      | 941     |
| 35    | 24     | 1   | 261                             | 176      | 589     | 384     | 302      | 680     |
| 35    | 24     | 2   | 353                             | 218      | 610     | 365     | 285      | 654     |

Table A.12. Concentration of TNC in plant fractions for treatment combinations of grazing cycle (GC) and stubble height (SH) sampled postgraze at the last grazing in 1993 and 1994. Data are reported in Chapter 4. TOPSTUB=top of stubble, BASESTUB=base of stubble, RHIZOME=roots and rhizomes.

| GC    | SH     | REP | 1993                           |          |         | 1994    |          |         |
|-------|--------|-----|--------------------------------|----------|---------|---------|----------|---------|
|       |        |     | TOPSTUB                        | BASESTUB | RHIZOME | TOPSTUB | BASESTUB | RHIZOME |
| - d - | - cm - |     | ----- g kg <sup>-1</sup> ----- |          |         |         |          |         |
| 7     | 8      | 1   | 97                             | 80       | 93      | 40      | 20       | 51      |
| 7     | 8      | 2   | 76                             | 71       | 84      | 44      | 26       | 45      |
| 7     | 16     | 1   | 106                            | 86       | 108     | 42      | 15       | 37      |
| 7     | 16     | 2   | 90                             | 65       | 109     | 45      | 24       | 40      |
| 7     | 24     | 1   | 82                             | 73       | 102     | 32      | 16       | 57      |
| 7     | 24     | 2   | 88                             | 80       | 116     | 28      | 13       | 15      |
| 21    | 8      | 1   | 96                             | 61       | 92      | 41      | 39       | 51      |
| 21    | 8      | 2   | 76                             | 57       | 96      | 43      | 29       | 22      |
| 21    | 16     | 1   | 99                             | 85       | 109     | 39      | 22       | 41      |
| 21    | 16     | 2   | 115                            | 87       | 91      | 43      | 24       | 45      |
| 21    | 24     | 1   | 47                             | 53       | 88      | 43      | 18       | 22      |
| 21    | 24     | 2   | 60                             | 52       | 98      | 26      | 11       | 18      |
| 35    | 8      | 1   | 68                             | 60       | 90      | 50      | 42       | 54      |
| 35    | 8      | 2   | 100                            | 79       | 90      | 65      | 46       | 43      |
| 35    | 16     | 1   | 91                             | 79       | 111     | 43      | 34       | 48      |
| 35    | 16     | 2   | 91                             | 75       | 112     | 57      | 42       | 62      |
| 35    | 24     | 1   | 71                             | 67       | 97      | 34      | 15       | 76      |
| 35    | 24     | 2   | 67                             | 57       | 90      | 47      | 10       | 57      |

Table A.13. Concentration of N in plant fractions for treatment combinations of grazing cycle (GC) and stubble height (SH) sampled postgraze at the last grazing in 1993 and 1994. Data are reported in Chapter 4. TOPSTUB=top of stubble, BASESTUB=base of stubble, RHIZOME=roots and rhizomes.

| GC    | SH     | REP | 1993                           |          |         | 1994    |          |         |
|-------|--------|-----|--------------------------------|----------|---------|---------|----------|---------|
|       |        |     | TOPSTUB                        | BASESTUB | RHIZOME | TOPSTUB | BASESTUB | RHIZOME |
| - d - | - cm - |     | ----- g kg <sup>-1</sup> ----- |          |         |         |          |         |
| 7     | 8      | 1   | 18                             | 7        | 5       | 18      | 10       | 3       |
| 7     | 8      | 2   | 13                             | 5        | 4       | 16      | 13       | 5       |
| 7     | 16     | 1   | 9                              | 4        | 7       | 13      | 13       | 4       |
| 7     | 16     | 2   | 8                              | 7        | 7       | 13      | 11       | 9       |
| 7     | 24     | 1   | 8                              | 6        | 3       | 12      | 13       | 7       |
| 7     | 24     | 2   | 9                              | 3        | 6       | 12      | 15       | 5       |
| 21    | 8      | 1   | 9                              | 4        | 7       | 13      | 11       | 4       |
| 21    | 8      | 2   | 8                              | 6        | 7       | 14      | 11       | 8       |
| 21    | 16     | 1   | 4                              | 3        | 6       | 8       | 10       | 3       |
| 21    | 16     | 2   | 9                              | 4        | 9       | 10      | 11       | 4       |
| 21    | 24     | 1   | 7                              | 4        | 6       | 9       | 13       | 7       |
| 21    | 24     | 2   | 8                              | 4        | 7       | 13      | 16       | 9       |
| 35    | 8      | 1   | 8                              | 7        | 3       | 10      | 4        | 3       |
| 35    | 8      | 2   | 6                              | 3        | 9       | 13      | 10       | 10      |
| 35    | 16     | 1   | 7                              | 8        | 7       | 9       | 11       | 5       |
| 35    | 16     | 2   | 4                              | 7        | 8       | 10      | 11       | 6       |
| 35    | 24     | 1   | 3                              | 7        | 7       | 12      | 13       | 7       |
| 35    | 24     | 2   | 2                              | 7        | 3       | 14      | 17       | 7       |

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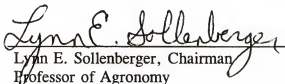
## BIOGRAPHICAL SKETCH

Carlos G.S. Pedreira was born in São Paulo, SP, Brazil, on the 17<sup>th</sup> of July 1963. He is the older son of Wladimir and Sônia E.S. Pedreira and he has a brother, Marcelo. In December of 1987, Carlos received the degree of "Engenheiro Agrônomo" from Escola Superior de Agricultura "Luiz de Queiroz" of the Universidade de São Paulo in Piracicaba, SP, Brazil. He then worked as a research assistant at the Instituto de Zootecnia in Nova Odessa, SP, Brazil during 1988, and with the São Paulo State Extension Service for half of 1989.

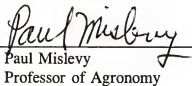
In August of 1989, he came to the USA and enrolled at the University of Georgia in Athens, to pursue graduate training in agronomy. He worked under the direction of Dr. R. Harold Brown, specializing in forage physiology, and received the degree of Master of Science in March of 1992. In June of 1992, he moved to Gainesville and continued his graduate training at the University of Florida, where he has served as Graduate Teaching Assistant in the Agronomy Department. He specializes in forage production and management under the direction of Dr. Lynn E. Sollenberger, and is currently a candidate for the degree of Doctor of Philosophy.

Carlos is a member of the American Society of Agronomy, Crop Science Society of America, the American Forage and Grassland Council, and Gamma Sigma Delta, the Honor Society of Agriculture.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

  
Lynn E. Sollenberger, Chairman  
Professor of Agronomy

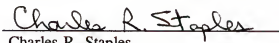
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Paul Mislevy  
Professor of Agronomy

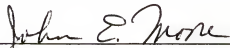
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Associate Professor of Agronomy

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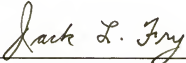
  
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Professor of Dairy and Poultry Sciences

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as a partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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